



Lower Duwamish Waterway Slip 4 Early Action Area

Engineering Evaluation/ Cost Analysis

Submitted to

U.S. Environmental Protection Agency, Region 10
1200 Sixth Avenue
Seattle, WA 98101

Submitted by

City of Seattle
King County

Prepared by



February 10, 2006

integral



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7900 SE 28th Street
Mercer Island, WA 98040

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ACRONYMS AND ABBREVIATIONS

AET	apparent effects threshold
AOC	Administrative Order on Consent
ARARs	applicable or relevant and appropriate requirements
BEHP	bis(2-ethylhexyl)phthalate
bgs	below ground surface
BMP	best management practice
CAD	confined aquatic disposal
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPC	chemicals of potential concern
CSL	cleanup screening levels
CSO	combined sewer overflow
CTM	Candidate Technologies Memorandum
CWA	Clean Water Act
cy	cubic yard
DMMP	Dredged Material Management Program
DRE	destruction removal efficiency
DW	dry weight
EAA	Early Action Area
Ecology	Washington Department of Ecology
EE/CA	engineering evaluation/cost analysis
ENR	enhanced natural recovery
EOF	emergency sewer overflows
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
ESA	Endangered Species Act
GRA	general response action
HHRA	human health risk assessment
HPAHs	high molecular weight polycyclic aromatic hydrocarbons
HTTD	high-temperature thermal desorption
ICIP	Institutional Control Implementation Plan
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
LPAHs	low molecular weight polycyclic aromatic hydrocarbons

LTMRP	Long-Term Monitoring and Reporting Plan
MCUL	minimum cleanup level
MLLW	mean lower low water
MNR	monitored natural recovery
MTCA	Washington State Model Toxics Control Act
MUDs	multiuser disposal sites
NCP	National Contingency Plan
NFA	No Further Action
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NTCRA	non-time-critical removal action
O&M	operation and maintenance
OC	organic carbon
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PSDDA	Puget Sound Dredged Disposal Analysis
QA/QC	quality assurance/quality control
RAO	removal action objective
RCRA	Resource Conservation and Recovery Act
RD/RA	removal design / removal action
RDC	Regional Disposal Company
RI/FS	remedial investigation and feasibility study
RM	river mile
ROD	Record of Decision
SEA	Striplin Environmental Associates
SCL	Seattle City Light
SCWG	Source Control Work Group
SD	storm drain
SMS	Washington State Sediment Management Standards
SOW	Statement of Work
SPU	Seattle Public Utilities
SQS	sediment quality standards
SVOC	semivolatile organic compound
TBCs	to be considered requirements
TBT	tributyl-tin
TCLP	Toxicity characteristic leaching procedure
TOC	total organic carbon
TPH	total petroleum hydrocarbons

TSCA	Toxic Substances Control Act
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
UST	underground storage tank
VOC	volatile organic compound
WDFW	Washington Department of Fish and Wildlife
WDOH	Washington Department of Health

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EXECUTIVE SUMMARY

The City of Seattle and King County are planning a sediment removal action for early cleanup of contaminated sediments in the Slip 4 Early Action Area (EAA) of the Lower Duwamish Waterway (LDW) Superfund Site in Seattle, Washington. Slip 4 is one of seven areas within the LDW that have been identified by the U.S. Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology) as candidate areas for early cleanup because sediments in these areas are associated with greater ecological and/or human health risk. The goal of this sediment cleanup is to significantly reduce unacceptable risks to the aquatic environment resulting from potential exposure to contaminated sediments in the slip. This cleanup will also reduce potential human health and ecological risks associated with polychlorinated biphenyls (PCBs) in sediment within the LDW.

This report presents the engineering evaluation/cost analysis (EE/CA) for the Slip 4 EAA removal action. It presents background information on the site, discusses available data and the proposed boundary of the removal action, documents the development and evaluation of alternatives for conducting the non-time-critical removal action (NTCRA), and discusses the rationale for the recommended removal action. Following public comment on this EE/CA, EPA, in consultation with Ecology, will select the removal alternative that will be implemented by the City and King County.

SITE CHARACTERIZATION AND RISK ASSESSMENT

Slip 4 is located on the east bank of the LDW, approximately 2.8 miles from the southern end of Harbor Island. The slip encompasses approximately 6.4 acres and is approximately 1,400 feet long, with an average width of 200 feet. Properties immediately adjacent to Slip 4 are currently owned by Crowley Marine Services, First South Properties, King County, and The Boeing Company. Crowley owns the majority of the submerged land within the Slip 4 EAA. A part of Crowley's submerged land (called the "inner berth") was historically dredged and permitted for navigation uses. The cleanup alternatives (summarized below) may affect Crowley's navigation uses on their land.

Numerous historical environmental investigations have included the collection of sediment data in Slip 4. Four sediment investigations were conducted in Slip 4 between 1990 and 1999. These investigations included an EPA site investigation (Weston 1999), a National Oceanic and Atmospheric Administration (NOAA) sediment characterization of the Duwamish River (NOAA 1998), a site assessment (Landau 1990), and a dredged material characterization (Exponent 1998). Results of these investigations are summarized in Section 2.3.1 of this report, and the resulting data were described in detail by SEA (2004).

Additional characterization data were collected in Slip 4 in 2004 (Integral 2004a). The initial investigation in April 2004 included collection of surface sediment samples at 29 locations, subsurface cores at 11 locations, and one intertidal composite sample. Bank samples were collected at six locations in July 2004. These investigations are summarized in Section 2.3 of this report and are described in detail by Integral (2004a).

Previous upland investigations adjacent to Slip 4 have included soil and groundwater sampling. These investigations were generally conducted as part of site assessments during property transfers, in conjunction with underground storage tank removal, or during construction when visible contamination (e.g., petroleum-staining) was observed or excavated soil required testing prior to disposal. A Resource Conservation and Recovery Act (RCRA) corrective action is being conducted at Boeing Plant 2. These investigations are also described in SEA (2004).

The removal action boundary encompasses approximately 3.6 acres in the northern half of Slip 4, as shown in Figure 2-18. The development and rationale for the proposed boundary for the Slip 4 removal action is described in the *Revised Draft Technical Memorandum on Proposed Boundary of the Removal Action*, contained in Appendix A of this report. This boundary memorandum was subject to public stakeholder review and comment. Development of the preliminary removal action boundary focused on the areal extent of PCBs because the historical data showed that PCBs were the primary contaminant of concern (SEA 2004); however, full-suite Washington State Sediment Management Standards (SMS) analyses were conducted, and all SMS analytes were considered. Areas where other chemicals exceeded the SMS Cleanup Screening Level (CSL) criteria were encompassed within the area exceeding PCB criteria; there are only two slight Sediment Quality Standard (SQS) exceedances outside the removal action boundary. All surface and subsurface sediment data were considered in developing the preliminary boundary. Additional bank soil and sediment data were collected in 2005 (Parametrix 2005; CH2M Hill 2005a; Bach 2005a, pers. comm.) and are summarized in this EE/CA. These data were used in this EE/CA to refine the boundaries of the removal action on the eastern bank of the slip.

The streamlined risk assessment, presented in Section 2.4, supports the need for the removal action. The ecological risk assessment for Slip 4 focused on the benthic invertebrate community by comparing chemical concentrations in surface sediments to the SMS. PCBs, bis(2-ethylhexyl) phthalate (BEHP), phenol and indeno[1,2,3-c,d]pyrene in surface sediments within the Slip 4 EAA exceed promulgated SMS standards for protection of benthic organisms. More mobile receptors (i.e., fish and wildlife) were assessed in the Phase 1 ecological risk assessment (ERA) for the LDW. The Phase 1 ERA indicted that PCB exposure concentrations were greater than concentrations associated with adverse effects for fish and great blue herons (based on egg data). Arsenic and copper were associated with adverse effects in fish. Other chemicals with exposure estimates greater than no-effects levels but less than the adverse-effects level for one or

more fish or wildlife species included PAHs, mercury, tributyltin (TBT), lead, and arsenic. The removal action is also supported by a summary of the LDW Phase 1 human health risk assessment that includes a list of potential risks to human health associated with PCBs in the LDW. In summary, contaminants found in Slip 4 sediments may have direct benthic community effects, and likely contribute to potential risks throughout the LDW to other ecological receptors and humans through diet exposure.

The proposed removal action will address ecological risks associated with contamination of sensitive ecosystems, which is indicated by the presence of PCBs above the SQS in surface sediments. These sediments provide important habitat for benthic invertebrates and juvenile salmonids, as well as other fish and shorebirds. The proposed removal action will also indirectly reduce human exposure to chemicals by removing or isolating sediment containing bioaccumulative chemicals (i.e., PCBs) that are found in seafood.

Areas in the LDW outside of the Slip 4 removal action boundary will continue to be evaluated by the LDWG, EPA, and Ecology under the LDW Remedial Investigation and Feasibility Study (RI/FS). The LDW RI/FS will include a baseline ecological and human health risk assessment to evaluate potential risks to human health and the environment posed by sediments in the LDW site, and will evaluate cleanup alternatives for areas of the site not addressed by the early actions.

GOAL, SCOPE, AND OBJECTIVES OF THE REMOVAL ACTION

The goal of the removal action at Slip 4 is to conduct an early cleanup that significantly reduces exposure of ecological and human receptors to sediment contamination, thereby reducing or eliminating adverse effects on biological resources in the removal area. The removal action objective is to:

- Reduce the concentrations of contaminants in post-cleanup surface sediments [biologically active zone (0–10 cm)] to below the state Sediment Quality Standards (SQS) for PCBs and other chemicals of interest.

The scope of the removal action includes approximately 3.6 acres within the removal boundaries identified in Section 3 of this EE/CA.

Potential sources of recontamination of Slip 4 sediments were also considered in defining the scope of this removal action. An evaluation of upland sources and source control efforts is included in Section 2.6 and Appendix B. Recontamination pathways of potential concern are bank erosion and stormwater flows that drain to outfalls in Slip 4. The cleanup alternatives described in the EE/CA include actions to address areas where eroding bank soils exceed the SQS.

Investigations by the City and King County indicate potentially significant ongoing sources of PCBs to Slip 4 from stormwater drainage. Control of stormwater sources is

outside the scope of this EE/CA. Ecology, King County, Seattle Public Utilities (SPU), and The Boeing Company are continuing to investigate and implement controls to address these sources. It is important that these sources are adequately controlled prior to construction of the Slip 4 removal action to minimize the potential for recontamination of Slip 4 sediments. Ecology will make the final decision regarding source control effectiveness and completeness (Ecology 2004). Following EPA and Ecology's assessment and before implementing cleanup actions, the City of Seattle and King County will consider whether or not source control is considered adequate to prevent recontamination to levels of concern.

IDENTIFICATION OF REMOVAL ACTION ALTERNATIVES

Section 4 includes an initial screening of technologies that may be applicable to cleanup of Slip 4. In Section 5, the retained technologies are developed into four removal alternatives that range from an emphasis on containment (with minimal removal) to an emphasis on removal (with minimal containment). The four alternatives developed for the Slip 4 removal area are:

- **Alternative 1** is based on a containment approach, primarily involving capping of contaminated sediments in place. Prior to capping, limited excavation and offsite disposal would occur at the head of the slip to accommodate outfall grading requirements, and on banks to ensure no net loss of aquatic habitat. Derelict piling and debris would be removed. Engineered sediment caps would be constructed over the entire Slip 4 removal area, including engineered slope caps on the affected banks. Portions of the cap would be thickened and graded to expand and enhance shallow subtidal and intertidal habitat. Alternative 1 limits the landowner's potential use of a permitted berthing area in the inner portion of the slip. As compensation, the City of Seattle is willing to purchase the affected property from the landowner if this alternative is selected.
- **Alternative 2** includes targeted removal of contaminated sediments at the head of the slip, along with capping. The objectives of dredging would be to remove near-surface material with the highest concentrations of contaminants, minimize changes to mudflat habitat at the head of the slip, and accommodate outfall flows. Piling and debris would be removed, and banks would be excavated to ensure no net loss of aquatic habitat. Engineered sediment caps would be constructed over the entire Slip 4 removal area, including engineered slope caps on the affected banks. Portions of the cap would be thickened and graded to expand and enhance shallow subtidal and intertidal habitat. Alternative 2 limits the landowner's potential use of a permitted berthing area in the inner portion of the slip. As compensation, the City of Seattle is willing to purchase the affected property from the landowner if this alternative is selected.

- **Alternative 3** includes dredging in the head and inner berth areas of the slip, along with capping. The objectives of dredging would be to remove near-surface material with the highest concentrations of contaminants, minimize changes to mudflat habitat at the head of the slip, accommodate outfall flows, remove contaminated material in the inner berth to re-establish historically permitted navigation depths (-15 feet MLLW), and attain a clean dredged surface in the inner berth. The dredging would be limited in scope to minimize impacts to adjacent structures and outfalls. Derelict piling and debris would be removed, and banks would be excavated to ensure no net loss of aquatic habitat. Engineered sediment caps would be constructed in the areas outside the inner berth, including engineered slope caps on the affected banks.
- **Alternative 4** includes the greatest amount of dredging within Slip 4 among the four alternatives. The dredging would have the overall objective of removing all contaminated material where reasonably feasible, but the dredging would be limited in scope to minimize impacts to adjacent structures and outfalls. As with Alternative 3, this alternative would re-establish historically permitted navigation depths in the inner berth. Piling and debris would be removed, and banks would be excavated to ensure no net loss of aquatic habitat. To minimize habitat disturbances by the deepening, the areas outside the inner berth would be backfilled with clean material. In areas where dredging could not remove all contaminated materials, the backfill would be designed to function as a cap. Engineered slope caps would also be constructed in bank areas.

In developing the removal alternatives, consideration was also given to a “maximum feasible removal” alternative, involving removal of most or all of the contaminated sediments within Slip 4, with an objective of avoiding the need for capping. Site limitations (including slope stability, structural stability of piers, outfalls, and bulkheads, and depth of contamination) would require extensive engineering measures to accomplish complete removal of all contaminated material. This approach would offer potentially greater long-term effectiveness because most of the contaminated materials would be removed from the site. However, it would have greater short-term impacts during construction, could require two construction seasons to implement, and would have substantially greater incremental costs than other, equally protective alternatives. The incremental cost of this approach is considered to be substantial and disproportionate to any benefits, and therefore the “maximum feasible removal” approach was not carried forward.

A no-action alternative was not considered for the Slip 4 removal area because it would not satisfy the removal action objectives or meet the needs and purposes of a NTCRA.

ANALYSIS AND RECOMMENDATIONS

The four removal alternatives are analyzed in Sections 5 and 6 with regard to EPA's criteria of effectiveness, implementability, and cost. This analysis is summarized below:

- **Effectiveness:** The effectiveness evaluation considers overall protection of human health and the environment, achievement of the removal action objective, compliance with applicable or relevant and appropriate requirements (ARARs), reduction of toxicity, mobility, or volume through treatment, short-term effectiveness, and long-term effectiveness and permanence. For overall effectiveness, Alternative 2 ranks highest, followed by Alternatives 1, 4, and 3. Each alternative would provide overall protection of human health and the environment and can achieve the removal action objectives. Each alternative can be implemented in compliance with ARARs. Alternative 2 provides the greatest quantity and highest quality habitat for threatened Puget Sound chinook and Coastal/Puget Sound bull trout, with Alternative 1 providing slightly less habitat benefits. Alternatives 3 and 4 would significantly decrease shallow subtidal and lower intertidal habitat area and would require more armoring, which may decrease habitat quality. Alternatives 1 and 2 are similar in their short-term effectiveness and are not expected to pose significant recontamination risk outside the removal area. Due to the greater amount of dredging and longer project duration, Alternatives 3 and 4 would pose a greater short-term risk of recontamination caused by dredging and would have greater short-term water quality impacts during dredging. Each alternative would be effective in the long-term; however the consequences of possible cap erosion would be greatest under Alternative 1. The potential for erosion is greatest under Alternatives 3 and 4 (due to navigation), and hence Alternatives 3 and 4 may require somewhat greater maintenance over the long-term. Each alternative would include institutional controls, long-term monitoring, and periodic reviews to ensure long-term protectiveness.
- **Implementability:** The implementability evaluation considers the technical and administrative feasibility of implementation, as well as the availability of materials, equipment, and services. For overall implementability, Alternatives 1 and 2 rank highest, followed by Alternatives 3 and 4. Each of the alternatives can reliably be implemented; however, Alternatives 3 and 4 would require additional consideration of design, monitoring, and construction elements so that a clean sediment surface is left in the inner berth and in adjoining areas south of the removal boundary. Under Alternatives 3 and 4, removal of under-pier sediments and placement of under-pier cap material would also require special provisions.
- **Cost:** The cost evaluation considers capital costs, long-term monitoring and maintenance costs, and total present worth costs. Alternative 1 is the least expensive alternative, followed by Alternatives 2, 3, and 4. Alternative 2 would

cost approximately 15 percent more than Alternative 1. Alternative 3 would cost roughly 50 percent more than Alternative 1. Alternative 4 would cost roughly twice as much as Alternative 1.

The City and King County recommend Alternative 2 because it represents the most practical and cost-effective balance of contaminant removal and containment while maximizing long-term effectiveness, providing the greatest habitat benefits, and minimizing potential long-term maintenance requirements.

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1 INTRODUCTION

The City of Seattle and King County are planning a sediment removal action for early cleanup of contaminated sediments in the Slip 4 Early Action Area (EAA) of the Lower Duwamish Waterway (LDW) Superfund Site in Seattle, Washington (Figure 1-1). The goal of this sediment cleanup is to significantly reduce unacceptable risks to the aquatic environment resulting from potential exposure to contaminants in sediments in the slip. This cleanup will also reduce potential human health risks associated with polychlorinated biphenyls (PCBs) in sediment within the LDW. This report presents the engineering evaluation/cost analysis (EE/CA) for the Slip 4 EAA removal action.

1.1 PROJECT BACKGROUND

The LDW was added to the U.S. Environmental Protection Agency's (EPA's) National Priorities List (Superfund) in September 2001 because of chemical contaminants in sediments. The key parties involved in the LDW site are the Lower Duwamish Waterway Group (LDWG) (composed of the City of Seattle, King County, the Port of Seattle, and The Boeing Company), EPA, and Washington Department of Ecology (Ecology). EPA is the lead regulatory agency for the sediment investigation and cleanup work under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); Ecology is the lead regulatory agency for source control work. The LDWG is voluntarily conducting the LDW Remedial Investigation and Feasibility Study (RI/FS) under an Administrative Order on Consent (AOC). The City of Seattle and King County are performing the Slip 4 characterization and EE/CA under Tasks 9 and 10 of the LDWG AOC and associated Statement of Work (SOW), and per requirements of the Slip 4 Revised Work Plan (Integral 2004b).

The first phase of the LDW RI used existing data to evaluate the nature and extent of chemical distributions in LDW sediments and presented preliminary risk estimates (Windward 2003c). Information obtained during the LDW Phase 1 RI was used to identify locations in the LDW that could be candidates for early cleanup action (Windward 2003a,b). Compared to the final remedial action decision process [which includes development of a RI/FS, Proposed Plan, and Record of Decision (ROD)], removal actions are generally defined as quickly implementable actions designed to eliminate or minimize known, significant risk from Superfund sites. Slip 4 was identified as a candidate early action site by EPA and Ecology (Windward 2003a) based primarily on elevated concentrations of PCBs.

The process used by EPA and Ecology to identify early action sites followed both the National Contingency Plan (NCP), which requires that threats to human or animal populations, sensitive ecosystems, or other significant factors affecting the health or welfare of the public or environment be considered when identifying removal actions (40 CFR§300.415), and the Washington State Model Toxics Control Act (MTCA). MTCA

defines interim actions as “a remedial action that is technically necessary to reduce a threat to human health or the environment by eliminating or substantially reducing one or more pathways for exposure to a hazardous substance at a facility” (WAC 173-340-430) (Windward 2003a).

Existing information for the Slip 4 EAA was compiled by SEA (2004). That report included descriptions of the physical environment, potential chemical sources, sediment data collected between 1990 and 1998, and existing habitat and human uses of the slip. SEA (2004) also identified data gaps to be filled prior to the identification of the boundary of the removal action area. Sediment and bank chemistry data were collected in March and July 2004 (Integral 2004c,d,e; Landau 2004) to address these data gaps and were reported by Integral (2004a). These data were used to determine the boundary of the removal action (see Section 2 and Integral 2005) and form the basis for the planned removal action. Additional bank soil and sediment data were collected in 2005 (Parametrix 2005; CH2M Hill 2005a,b; Bach 2005a, pers. comm.) and are summarized in this EE/CA; these data were used to refine the boundaries of the removal action. Areas in the LDW outside of the Slip 4 removal action boundary will continue to be evaluated by the LDWG, EPA, and Ecology under the LDW RI/FS.

EPA determined that Slip 4 meets the criteria for initiating a removal action under CERCLA and that the proposed action is non-time-critical. As required for all non-time-critical removal actions (NTCRA) under CERCLA, this report presents the EE/CA for the Slip 4 EAA. EPA (1993) guidance states that the purposes of the EE/CA are to:

- Identify the objectives of the removal action
- Satisfy environmental review requirements for removal actions
- Provide a framework for evaluating and selecting among alternative technologies
- Analyze the cost, effectiveness, and implementability of various alternatives that may satisfy the objectives
- Satisfy administrative record requirements for documentation of removal action selection.

1.2 REPORT ORGANIZATION

This EE/CA follows the general format recommended by EPA (1993). It is organized into the following sections:

- Section 2 contains site background information, including site history, description of the physical environment, land use, ecological habitats, and previous sediment investigations and data collected at the site. This section also includes the results of a streamlined risk evaluation and a description of upland source control actions.

- Section 3 describes the removal action scope, goals, and objectives.
- Section 4 identifies cleanup technologies applicable to the removal action.
- Section 5 identifies and analyzes the removal action alternatives.
- Section 6 presents a comparative analysis of the alternatives.
- Section 7 identifies the recommended removal alternative.
- Section 8 contains the report reference list.

Appendix A contains the EPA-approved technical memorandum (Integral 2005) describing the proposed removal action boundary and the rationale used to identify the boundary. As discussed in Section 2, this boundary has been refined using new data reported by Parametrix (2005), CH2M Hill (2005a,b), and Bach (2005a, pers. comm.). Appendix B contains sampling results from the source control efforts undertaken by the City. Finally, Appendix C provides approximate post-construction elevations and habitat areas for all four alternatives.

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2 SITE CHARACTERIZATION

This section describes the physical, biological, and chemical characteristics of the Slip 4 EAA. The information contained in this section is compiled from the *Summary of Existing Information and Identification of Data Gaps* report (SEA 2004), the *Cruise and Data Report* (Integral 2004a), and investigations conducted by Parametrix (2005), CH2M Hill (2005a,b), and Bach (2005a, pers. comm.). Additional details and supporting information can be found in the original reports.

2.1 SITE DESCRIPTION AND HISTORY

2.1.1 Location

Slip 4 is located on the east bank of the LDW, approximately 2.8 miles from the southern end of Harbor Island (see Figure 1-1). The slip is approximately 1,400 feet long, with an average width of 200 feet (Figure 2-1). The slip encompasses approximately 6.4 acres, from the head of the slip to the confluence with the LDW main channel.

The Duwamish River flows 13 miles from the confluence of the Black and Green rivers to Elliott Bay. The LDW includes the lower reach of the river, extending from the upper turning basin (Turning Basin 3) to the southern tip of Harbor Island. The East and West waterways, discharging to Elliott Bay, are not part of the LDW Superfund site.

The Duwamish shoreline is dominated by industrial and commercial activities, such as cargo handling and shipping, ship building and repair, aircraft manufacture, food processing, and various manufacturing facilities (Windward et al. 2005). The LDW is a major cargo shipping route, and a navigation channel is maintained by dredging. Most of the Duwamish shoreline has been highly modified by human activity. Shoreline structures constructed in support of the commercial, industrial, and shipping activities that dominate the lower waterway include bulkheads, wharfs, piers, and steeply sloped banks armored with riprap. There are also numerous historic and current piped outfalls that discharge treated wastewater, stormwater, or combined sewer overflows to the LDW.

In addition to industrial and commercial activities, there are also a number of parks and restored natural areas along the shoreline, as well as residential neighborhoods near the river. Undeveloped shorelines and intertidal habitat are primarily associated with habitat restoration areas such as Kellogg Island, Hamm Creek or the Norfolk combined sewer overflow (CSO). These undeveloped areas are dispersed along the river, and, with the exception of Kellogg Island, most are relatively small (< 1 acre) (Windward 2003c). Residential areas occupy approximately 40 percent of the Duwamish River watershed; the Georgetown neighborhood is located near Slip 4 (Windward 2003c).

2.1.2 Site History

Slip 4 was created in the early 1900s during filling and channelization of the Duwamish River. The slip itself is an arc-shaped remnant of a former Duwamish River meander. Since its creation, aquatic land uses in Slip 4 have included log storage and shipping activity. The earliest land uses in the surrounding upland areas were residences and log storage and other timber-related activities. Beginning in approximately the 1930s, land uses on the northwest side of the slip included a sawmill, lumber yard, hydraulic equipment manufacturing, and pole yard. On the southeast side of the slip, uses included a machine shop, lime plant, and asphalt plant. Airplane manufacturing adjacent to Slip 4 began sometime before 1960. Additional information on historic activities at Slip 4 is reported by SEA (2004).

Aquatic land uses and activities in Slip 4 have been supported by construction of over-water structures (see Section 2.1.3.2) and dredging. The most recent dredging activities in Slip 4 were conducted in 1981 and 1996 to allow barge and tug access to docks and piers on the northwest side of the slip (Figure 2-2). The 1981 dredging removed sediment from nearly all of the northwest side of the slip (from the shoreline to the centerline) to a depth of -15 feet mean lower low water (MLLW). The 1996 dredging was also along the northwest side of the slip, but was restricted to the outer half along the Crowley marine pier. Sediment was removed to a depth of -17 feet MLLW (including overdredge). The federal navigation channel outside Slip 4 is currently maintained at -15 feet MLLW from the upper turning basin to Slip 4 and -20 feet MLLW from Slip 4 to the 1st Avenue South Bridge (USACE 1983).

One recorded spill was reported in Slip 4. In 1985, an estimated 50 gallons of oil was discharged to Slip 4 from the Georgetown Steam Plant flume outfall at the head of the slip (Brugger 1985, pers. comm.) (Figure 2-1).

Current land use and ownership are described in Section 2.1.7.

2.1.3 Physical Environment

2.1.3.1 Bathymetry and Topography

The slip is relatively shallow, ranging from +5 feet MLLW¹ at the head of the slip to approximately -20 feet MLLW at the mouth (Figure 2-3). The shallowest depths occur at the head and along the eastern shoreline where the bottom relief gradually slopes to the current and historical dredging boundary located approximately halfway across the slip. At low tide, bottom sediments are exposed at the head and along the eastern shoreline. In areas of historical dredging along the western half of the slip, the original (1981) dredged

¹ All elevations in this report are based on the U.S. Survey MLLW vertical datum and are given in feet.

depths were -15 feet MLLW (Figure 2-3). The middle and outer berthing areas were later dredged to -17 feet MLLW in 1996. Within the inner berthing area, which was last dredged to -15 feet MLLW in 1981, considerable shoaling has occurred, and bottom elevations currently range from -3 to -13 feet MLLW.

The top of bank elevation ranges from about +12 to +18 feet MLLW. Much of the bank is within the tidal range (the extreme low tide is approximately -4 feet MLLW; extreme high tide is approximately +13 feet MLLW; the mean higher high tide is +11.1 feet MLLW). The bank on the west side of the slip under the Crowley pier includes steeply sloped riprap next to a vertical bulkhead, with sediment deposits under the outer edge of the pier. The bank slope is nearly vertical at the bulkheads located on the eastern shoreline at First South Properties, and steeply sloping at the head of Slip 4. The southern portion of the eastern shoreline on the Boeing property is steeply sloped and armored with riprap.

The upland areas adjacent to Slip 4 are mostly flat (see Figure 2-1). A small man-made hill is located near the mouth of the slip in the landscaped park area at Boeing.

2.1.3.2 Structures and Debris

Structures in and adjacent to Slip 4 are shown in Figure 2-1. The most obvious structure in Slip 4 is Crowley's pier and berthing area along the western shoreline. The pier is constructed of concrete piling supporting a concrete deck that extends over the water. The berthing areas at the mouth of Slip 4 are currently used for barge loading and unloading. There are no other docks in Slip 4.

Portions of the east shoreline (First South Properties) and the bank at the head of the slip are lined with discontinuous segments of timber piles and wood lagging supported bulkheads and cinderblock bulkheads. Parts of a derelict wooden loading structure remain on the western shoreline between the Crowley pier and the head of the slip.

There is a considerable amount of concrete debris and partially buried logs and piling near the toe of the banks around the head of the slip. There is also a series of large timber skids at the head of the slip, in the northwest corner. The skids are mostly buried by sediment.

2.1.3.3 Outfalls and Seeps

Table 2-1 lists the five public outfalls that discharge to Slip 4. These public outfalls, including storm drains and emergency sewer overflows (EOF), are located at the head of Slip 4 (Figure 2-1):

- I-5 storm drain (SD)
- King County Airport SD #3/ PS44 EOF

- North Boeing Field SD
- East Marginal Way PS EOF
- Georgetown flume.

There are also numerous private storm drains and piped outfalls located along the Slip 4 shoreline (Figure 2-1). Additional information on discharges from the Slip 4 outfalls and associated source control activities is provided in Section 2.6 and Appendix B of this report and in SEA (2004).

Two seeps were located on the east side of Slip 4 during the LDWG survey in 2004 (Windward 2004b). The seep locations are shown in Figure 2-1.

2.1.3.4 Utility Crossings

Other than storm drainage/EOF pipes, no other utility crossings in Slip 4 have been identified. An underwater telephone cable crosses the Duwamish immediately north of Slip 4.

2.1.4 Currents and Circulation

Circulation in Slip 4 is influenced primarily by general circulation patterns in the Duwamish Waterway and secondarily by slip geometry. Surface water and groundwater discharge volumes to Slip 4 are relatively small compared to river input. Stormwater discharge can likely have intermittent and short-term effects on circulation depending on the magnitude and duration of the discharge and river and tidal stages. No information on specific circulation patterns, exchange times, or salinity is available for Slip 4 at this time. However, there have been numerous hydrologic studies in the Duwamish Waterway, and general circulation patterns and characteristics in the vicinity of Slip 4 are described here. Additional information on river-wide hydrology has been described in Windward (2003c).

The lower reach of the Duwamish Waterway is a saltwater wedge estuary with a lower layer of nearly undiluted seawater moving upstream from Puget Sound and a surface layer of riverine fresh water mixed with saltwater. The estuary is tidally influenced from its mouth extending upriver to near the Black River convergence [river mile (RM) 12.1]. The saltwater wedge is present in the vicinity of Slip 4 throughout the year, and, in the vicinity of Slip 4, the waterway generally remains stratified with a distinct freshwater/low salinity surface layer overlying a saltwater bottom layer.

Circulation in the Duwamish Waterway is controlled by freshwater inflow and tidal action. In general, on a rising tide, water in both the bottom saltwater wedge and surface layer flows upstream. On a falling tide, the flow is downstream. Although water moves upstream and downstream with the tides, circulation in the vicinity of Slip 4 consists of a

net downstream flow in the surface layer and a net upstream flow in the salt wedge layer (King County 1999).

Tidal effects primarily control the water elevation in the Duwamish Waterway (King County 1999). Tidal elevations at Slip 4 range from extreme lows of approximately -4 feet MLLW to extreme highs of approximately +13 feet MLLW. River discharge (controlled by releases from the Howard Hanson Dam on the Green River) has a lesser influence on water elevations in the lower Duwamish.

No current studies have been conducted in Slip 4. As Slip 4 is a quiescent off-channel feature, currents within the slip are expected to be generally low and variable. However, significant localized and episodic currents are associated with outfall flows (particularly during storm events) and propeller wash from navigation. These localized and episodic currents will be considered during design of the removal action project.

2.1.5 Sediment Transport

Sediment transport is influenced by many variables, including circulation, sediment loading from upland sources, channel morphology, and resuspension (e.g., propeller scour, dredging) (Windward 2003b). Sediment transport studies completed in the lower Duwamish River are described by Windward (2003c). A more comprehensive sediment transport study for the LDW site is currently underway and will likely be completed in 2006 (Windward and QEA 2004). In general, studies to date have described the lower Duwamish River as a net depositional environment, although sediment erosion and transport may still occur along some reaches and on a local scale. Stormwater and river input are sources of sediment to Slip 4; atmospheric and tidal contributions are comparatively minor. Stormwater controls in recent years have likely decreased sediment inputs from this source.

No detailed sediment transport or deposition studies have been conducted in Slip 4. McLaren and Ren (1994) suggested a net transport of fine-grained material from the river into Slip 4. Tetra Tech (1988b) estimated a minimum sediment accumulation rate of 0.8 cm/yr based on PCB concentrations in subsurface sediments. However, this estimate was based on very limited data and numerous assumptions, and may be less than the actual sedimentation rate.

Actual sedimentation rates may vary significantly with location. Crowley dredging records indicate that between the 1981 and 1996 dredging events approximately 1 to 1.5 feet of sediment accumulated in the center of the berthing area, converting to an estimated sediment accumulation rate of 2–3 cm/yr in this location. Much thicker sediment accumulations have occurred in the inner berthing area, suggesting that dredging has created an area of preferential deposition. Ships (e.g., propeller wash, anchor drag) also affect localized sediment transport; specific information on ship traffic in Slip 4 will be evaluated in the design of the removal action.

2.1.6 Geology and Hydrogeology

Landau (1990) described the geology of Slip 4 upland areas based on subsurface soil borings. They described a surface fill layer, underlain by tideflat and river deposits. Surface soils surrounding Slip 4 consist of 4–14 feet of fill. The fill is generally sand and silty sand and possibly layers of silt (Landau 1990). The native tideflat deposits below the fill material are generally silt and silty fine sand; remnants of roots and wood fragments in this material indicate that this was the original ground surface prior to filling. Alluvial sand and silt from the Duwamish River flood plain are found below the silt and silty sand layer (Landau 1990).

Within Slip 4, surface sediments range from less than 10 percent to over 80 percent fine material (i.e., clay and silt) (Figure 2-4). Subsurface sediment grain size also varies widely (1.8–91 percent fines) (Integral 2004a).

The entire Duwamish industrial area, including Slip 4, is underlain by a single, large alluvial aquifer system that extends from the water table to a depth of 70 to 80 feet below ground surface (bgs). In the vicinity of Slip 4, groundwater is typically encountered within 6 to 10 feet bgs. Hart Crowser (1989a,b) reported that groundwater flow in the immediate vicinity of Slip 4 is directed radially toward the slip at both high and low tides, although there is saltwater intrusion and mixing at high tide when the tide rises above the groundwater elevation. In contrast, Landau (1990) reported that groundwater flow is generally toward the slip at low tide and away from the slip at high tide with net flow toward the slip. Groundwater inland of the buried river channel probably flows to the channel and then along the channel to Slip 4 and the river (Harper-Owes 1985).

2.1.7 Current Land Use and Ownership

2.1.7.1 Commercial, Industrial, and Residential Activities

Slip 4 is located in a primarily industrial and commercial area; a small residential neighborhood is located about 0.25 mile from the slip. Properties immediately adjacent to Slip 4 are currently owned by Crowley Marine Services, First South Properties, King County, and The Boeing Company (see Figure 2-1). Land use at these properties is briefly described below. Additional information is provided by SEA (2004).

Crowley owns the pier and berthing facility on the northwestern side of Slip 4 (see Figure 2-1). The upland terminal is mostly paved and is used for storage or parking. Crowley currently leases the facility to a third party that is engaged in cargo and shipping activities. Barge and tug operations in support of these activities currently occur in the middle and outer berthing areas. The inner berthing area is not currently used for navigation because it is too shallow and because of concerns related to disturbing contaminated sediments. A crane rail line runs along the property shoreline adjacent to

the west boundary of the slip. Crowley also owns the majority of the submerged land in Slip 4 and the bank (below +10 feet MLLW) along the First South Properties' shoreline.

First South Properties is the current owner of the land northeast of the slip. Their ownership includes bank soils above +10 feet, but does not include any sediments in Slip 4. The property is currently occupied by Emerald Services for storage of portable toilets, storage tanks and containers, and large construction hauling/recycling containers and dumpsters. This parcel is partially paved. A trailer serves as an onsite office for the facility.

King County owns a small property and building northeast of First South Properties on East Marginal Way South. The building is a pump station associated with the Elliott Bay Interceptor (the sewer main running along the Duwamish to the West Point Treatment Plant).

The Boeing Plant 2 facility occupies 107 acres between East Marginal Way South and the Duwamish River, and borders the southeastern side of the slip (Weston 1998). Surface water runoff from approximately 17.5 acres on the north end of Plant 2 is discharged to Slip 4. Although much of the Plant 2 facility is used for storage, 12 buildings are used for manufacturing aluminum alloy, steel alloy, and titanium alloy parts for airplanes (Weston 1998). Building 2-122 is located adjacent to Slip 4. This building was built in the early 1990s to house the Integrated Aircraft Systems Laboratory (Boeing 1993, pers. comm.). The grounds between the parking area and Slip 4 now include public walking trails and a park. Except for this area, nearly all Plant 2 area is paved. Boeing also owns the submerged land in Slip 4 from its upland shoreline to the middle of the channel.

Weston (1998) reported that a single-family residence is located on Webster Street northeast of Building 2-122.

2.1.7.2 Navigation

Most navigation in Slip 4 is related to operations at Crowley. During the late 1990s and early 2000s, Crowley provided cargo transport primarily by barge. Tugs and barges operated and docked along the middle and outer berths in Slip 4. The inner berth was seldom, if ever, used due to the shallow depths in this area. Currently, there is no active shipping or cargo loading at the inner berth; the middle and outer berths are still used for barge moorage and loading.

Dredging has been permitted all along the Crowley pier (see Section 2.1.2, Figure 2-2). Dredging of Crowley's berths was originally permitted to -15 feet MLLW (USACE 1981) and later dredging in the middle and outer berths was permitted to -17 feet MLLW (including overdredge) (USACE 1995).

2.1.7.3 Recreational Activities

Recreational activities in Slip 4 are lessened by the surrounding industrial development and limited upland access. However, possible recreational activities within and near the slip may include kayaking, canoeing, and motorboating. Due to the extensive commercial and industrial use of the lower Duwamish River, activities such as swimming, SCUBA diving, and windsurfing are not common (King County 1999). However, there are small nonindustrial areas (e.g., parks) where swimming and wading could occur (Windward 2005b).

There is a small park on the southeastern side of Slip 4 that is maintained by Boeing. This street-end park is a public access site; however, no signage is evident at the park entrance. According to B.J. Cummings (2003, pers. comm.), the park is a popular spot for Boeing employees to eat lunch. Visitation by the general public is likely low because of the lack of signage and the general appearance that the park is privately owned. Besides picnicking, possible recreational activities at the park include walking and nature study.

Sport fishing in the Duwamish is focused primarily on salmon and bottomfish. There is currently a public health fish advisory recommending no consumption of resident fish (e.g., shiner perch, rockfish, English sole), shellfish or clams from the Duwamish River due to chemical contamination (WDOH 2005). Nonresident fish such as salmon are not included in this advisory. The salmon fishing season in the Duwamish Waterway area is open from November 1-30, with a two-fish daily limit, of which one may be a chinook (22-inch minimum size). The season opens again from December 16 until the end of February, with a one-fish daily limit (22-inch chinook minimum). Sport fishing within Slip 4 is possible, but the extent and frequency are unknown. The small public park at the mouth of Slip 4 has no public access to the Duwamish River. However, there are access points to the slip itself, and fishing could occur via access by boat and land.

2.1.7.4 Commercial and Tribal Fishing

Commercial and subsistence fishing occurs primarily in Elliott Bay, the East and West waterways, and in the Duwamish/Green River. Salmon are the most popular catch, but there is also a sport fishery for bottomfish near the mouth of the Duwamish.

Elliott Bay, the East and West waterways, and the lower Duwamish River are identified as usual and accustomed fishing areas for both the Muckleshoot and Suquamish tribes. Usual and accustomed fishing areas recognize commercial, subsistence, and ceremonial tribal fishing rights. Commercial fishing activities by tribal members are consistent with past treaties with the federal government and subsequent court decisions. The Muckleshoot Tribe is the only tribe with federally recognized treaty rights in the vicinity of Slip 4 (St. Amant 2003, pers. comm.; Windward 2005b). The Duwamish Tribe has been unsuccessful in its efforts to be federally recognized as an organized Indian tribe and therefore is ineligible for treaty fishing rights.

Muckleshoot tribal members harvest chinook, coho, chum, and steelhead salmon in these traditional fishing areas in late summer, fall, and winter. They employ set and drift gillnets and hook-and-line gear to meet their fish allotments. Tribal gill nets have been observed in Slip 4 in recent years.

Evidence of subsistence fishing (i.e., utilizing fish from the LDW as the sole source of protein) in the river is somewhat limited. Recent surveys have documented relatively high seafood consumption for several Puget Sound populations (Suquamish Tribe 2000; USEPA 1999a), some of which may be fishing the river for subsistence reasons. Marcia Henning, outreach coordinator for the state's Environmental Health Assessments, believes that many people who fish the river, including Samoan, Tongan, Vietnamese, Hmong, Lao, and Russian immigrants, many of whom do not speak English, are fishing for subsistence purposes (Welch 2002). However, a public health advisory recommending no consumption of resident fish was issued in 2005 (see Section 2.1.7.3). Subsistence/tribal fishing for resident fish may be limited at this time, but this use may change in the future.

2.1.8 Sensitive Ecosystems

2.1.8.1 Habitat

Slip 4 is located in a highly developed commercial-industrial area, and the shoreline and surrounding upland areas have been substantially modified and developed. Except for a small park that was created in the 1990s, most upland habitat has been eliminated. The park is partially landscaped with ornamental and native flowers, shrubs, grasses, and trees. Species characteristic of disturbed areas (e.g., blackberries) are present along the shoreline, slope, and paths.

Nearly all of the Slip 4 shoreline has been highly modified and includes berths and a pier, riprap (some mixed with sand and gravel), exposed geotextile material, bulkheads, and miscellaneous fill (Figure 2-5). The small areas of unarmored shoreline are generally steep, eroded slopes, vegetated by mixed grasses and shrubs. There is little overhanging vegetation.

Two basic aquatic habitat types can be identified at Slip 4 based on depth, sediment grain size, and general topography (Figure 2-5). The first is sandy mud or muddy shallow subtidal habitat. These areas are found along the center and northwest sides of Slip 4 at depths of -10 to -17 feet MLLW, and are over 60 percent fine-grained material. The second is intertidal mudflat at the head and on the southeast side of the slip, composed primarily of 30–60 percent fine-grained material. There are also hard structures such as pilings and riprap. The existing aquatic habitat in Slip 4 supports populations of benthic and epibenthic invertebrates, likely provides habitat for migratory and resident fishes, and may provide feeding and resting areas for shorebirds, waterfowl, and marine birds. Additional information on *onsite* uses is described in greater detail in Section 2.1.8.2.

Tanner (1991) identified 4.7 acres at the head of Slip 4 as one of 24 potential intertidal habitat restoration sites in the lower Duwamish estuary. Further evaluation by Metro (1993) ranked Slip 4 low for habitat restoration potential relative to the other sites. They reported that significant habitat restoration in the slip would require regrading the adjacent upland and shoaling dredged subtidal areas, and that sediment contamination issues should be addressed. However, based on its inclusion in the 1991 list, the Lower Duwamish Community Plan (Green-Duwamish Watershed Alliance 1998) included Slip 4 on its list of proposed habitat restoration projects for the lower Duwamish.

2.1.8.2 Biota

Benthic Invertebrates

No benthic community data for Slip 4 were found during this review. Benthic invertebrate sampling by the LDWG in 2004 did not include any sampling locations in Slip 4 (Windward 2005a). The following descriptions are based on communities in similar habitat types and the limited monitoring results from other locations in the Duwamish. Results of the 2003-2004 LDW clam, crab, and shrimp surveys are described in the *Shellfish* section below.

Cordell et al. (1994, 1996) sampled benthic invertebrate communities at two intertidal reference sites in the Duwamish: Kellogg Island and the turning basin. The grain sizes at these two locations are similar to intertidal areas at Slip 4, containing approximately 35 percent fines. Mean porewater salinities at Kellogg Island and Turning Basin No. 3 (10.8 and 5.3 ppt, respectively) likely bracket those at Slip 4. Intertidal benthic invertebrate assemblages were similar to other locations in the Duwamish River estuary. Although there were differences between sites, the dominant benthic macrofauna included nematodes, oligochaetes, the gammarid amphipod *Corophium* spp., the cumacean *Leucon* sp., the polychaetes *Manayunkia aesturina* and *Hobsonia florida*, and several species in the family *Spionidae*. The bivalve *Macoma* spp. was present at most stations. The benthic meiofauna (smaller marine organisms) community was dominated by harpacticoid copepods and nematode worms (Cordell et al. 1994, 1996).

There are several outfalls at the head of Slip 4 as well as smaller stormwater discharge pipes that may or may not be active (see Section 2.1.3.3). Discharges can dramatically affect and alter the benthic communities in their immediate vicinity. For example, a benthic community survey conducted off the Duwamish/Diagonal CSO and storm drain found localized increases in abundance of organic enrichment-tolerant species, such as *Capitella* sp., and an overall reduction in diversity (King County 1999).

It is important to note that the benthic invertebrates in intertidal and subtidal habitats of the lower Duwamish are important as prey organisms for resident and migratory fishes, including outmigrating juvenile salmon (Thom et al. 1989; Simenstad et al. 1991; Cordell et al. 1996) and for resident and migratory shorebirds (Battelle et al. 2001; Cordell et al.

2001). The epibenthic organisms that are important in the diets of salmonids and some shorebirds are abundant in areas of sand and silt and among gradually sloping riprap containing sand and gravel. However, areas of steeply sloping riprap under concrete berths or aprons are less productive feeding habitat for juvenile salmonids (Meyer et al. 1981).

Shellfish

Shellfish in the LDW include crab, shrimp, clams, and mussels. Windward (2004c) identified the beach along the east side of Slip 4 as high-quality clam habitat; the area at the head of the slip was categorized as low-quality habitat. Quantitative clam surveys included sampling at the east beach. The survey in July 2003 reported two clams [tentatively identified as horse clams (*Tresus capax*)] in Slip 4. In the August 2003 survey, Windward (2003c) reported finding eight clams in Slip 4, including two Baltic tellins (*Macoma balthica*), three bent-nose clams (*Macoma nasuta*) and two sand gapers (*Mya arenaria*). The resulting population estimate was 0.47 clams/foot² but there may be considerable uncertainty with this estimate as the distribution was highly variable and patchy.

Windward sampled clams for tissue analysis in the fall of 2004. Clams (primarily *Mya arenaria*) were collected from the beaches at the head of Slip 4 and along the east beach adjacent to First South Properties. Both sampling areas are within the proposed removal action boundary. Windward (2005a) reported that clams from the beach at the head of the slip had higher concentrations of total DDTs, total PCBs, high molecular weight polycyclic hydrocarbons (HPAHs), low molecular weight polycyclic aromatic hydrocarbons (LPAHs), and metals (including cadmium, chromium, lead, mercury, nickel, silver and zinc) compared to clams from other locations in the lower Duwamish River. Collocated beach sediment samples exceeded the Washington State Cleanup Screening Level (CSL, WAC 173-204) for total PCBs, several individual PAHs, and bis(2-ethylhexyl)phthalate, and exceeded the second lowest apparent effects threshold (2LAET) for total DDT. Metals in sediments did not exceed the sediment quality standards (SQS) in any of the LDW sediment samples. At the beach on the First South shoreline, PCBs in clams were higher than in other areas of the lower Duwamish. PCBs in sediment at this location were the second highest concentration reported in this LDW study and exceeded the CSL (Windward 2005a).

Other shellfish in the LDW include crabs, shrimp, and mussels. Windward (2004a) sampled one location along the Slip 4 southeast shoreline as part of a LDW crab and shrimp survey. Samples were collected quarterly. The catch in Slip 4 was two Dungeness crabs (*Cancer magister*) in the September 2003 survey, no crabs in the November 2003 survey, and one and five slender crabs (*Cancer gracilis*) in February and May 2004 surveys, respectively. No shrimp were caught in Slip 4. Mussels are observed on pier pilings in Slip 4.

Salmonids

The Duwamish River provides habitat for young and returning adult salmonids. General information on these species is summarized below. A comprehensive review of salmonid populations, life histories, and status in the Duwamish/Green River has been prepared by King County (2000) and can be consulted for additional information.

Salmon species currently in the Duwamish/Green River system include:

- Chinook salmon (*Oncorhynchus tshawytscha*)
- Coho salmon (*Oncorhynchus kisutch*)
- Chum salmon (*Oncorhynchus keta*)
- Pink salmon (*Oncorhynchus gorbuscha*)
- Steelhead trout (*Oncorhynchus mykiss*)
- Cutthroat trout (*Oncorhynchus clarki clarki*).

Upstream migration of adult salmonids occurs throughout the year but is greatest in late summer and fall. Adults tend to stay in shallow nearshore areas before proceeding upriver (King County 2000). Salmon spawning does not occur in the Duwamish River, but begins in the lower Green River (RM 24) and continues upstream (King County 2000). Both adults and juveniles are found in the LDW. The majority of salmonids in the lower Duwamish during the spring and summer are juveniles. In-water activities (e.g., dredging) that could interfere with salmon populations are currently prohibited or limited during the period from February 15 to September 30.

The importance of estuaries, and particularly shallow nearshore areas, in the early life history of salmonids has been well documented (Meyer et al. 1981; Thorpe 1994). These areas provide food and refuge from predators during acclimation to saltwater. Juvenile salmonid use of the Duwamish is well documented (Meyer et al. 1981; Weitkamp 2000; King County 2000). Meador (2000) confirmed juvenile salmon use in Slip 4, reporting that the catch per unit effort in Slip 4 was about 5 to 10 times higher than that for Kellogg Island on the same day. Windward performed juvenile salmon sampling near Kellogg Island, within Slip 4, and north and south of the mouth of the slip in May and June 2003. Results showed the variability of juvenile salmon use of these areas, with the catch at Kellogg Island 6 times greater than that for Slip 4 on the same day (Florer 2003, pers. comm.).

In general, the greatest juvenile salmonid densities are found over shallow, sloping, relatively soft mud beaches (King County 2000). Juveniles are most often found in water at least 1 foot deep but rarely deeper than 4 feet from the surface (USACE et al. 1994). Temporally, juvenile salmonids are most abundant in the Duwamish between mid-April and mid-June. Peak abundance periods are related to hatchery releases.

Tissue chemical concentrations in juvenile chinook from the LDW were obtained by the National Oceanic and Atmospheric Administration (NOAA) Fisheries in 2000 (Meador 2000) and the LDWG in 2003 (Windward 2004e). Both investigations included fish collected in Slip 4. Detected chemicals in whole-body juvenile chinook in Slip 4 included PCBs, DDT, and TBT. These data will be included in the LDW Phase 2 risk assessment (see Section 2.4).

Other salmonid species in the Duwamish are steelhead trout, coastal cutthroat, and bull trout. King County (2000) reports two Duwamish/Green River winter steelhead stocks: a native wild spawning population, and an early release hatchery stock. There is also a summer-run hatchery stock. Like the salmon species above, juvenile steelhead use shallow nearshore areas for feeding, refuge, and physiological transition from fresh to saltwater. Few data are available concerning the abundance of coastal cutthroat in the Duwamish/Green River basin. The Washington Department of Fish and Wildlife (WDFW) (2000) consider the Duwamish/Green coastal cutthroat stock distinct based the geographic distribution of its spawning grounds, but there are insufficient data to be absolutely certain. Eleven cutthroat trout were captured in beach seines from February to June 1994 (Warner and Fritz 1995). Information and data on bull trout presence, abundance, and distribution in the Duwamish/Green watershed is lacking, and the stock status is unknown (WDFW 1998). Watson and Toth (1994) stated "it is unclear whether the Green River supports a population of bull trout."

Nonsalmonid Fishes

The shallow nearshore areas in the Duwamish provide habitat for young and adults of over 40 different fish species (USACE 1983; Matsuda et al. 1968; Weitkamp and Campbell 1980; Meyer et al. 1981). Primary nonsalmonid fish species include English sole, Pacific staghorn sculpin, starry flounder, shiner perch, snake pricklyback, Pacific herring, and surf smelt (USACE 1983, USACE et al. 1994). Other estuarine species found in the Duwamish include rainbow trout, bass, bluegill, suckers, sunfish and dace (USACE et al. 1994). Juveniles of many of these fish species rear throughout the spring and summer on mud/sand intertidal substrates in estuarine areas of Puget Sound. A complete nonsalmonid fish species list for the Duwamish/Green River system was compiled by the USACE (1983) and Windward (2003c), and is provided in Table 6-5 of SEA (2004).

Wildlife

Bird species likely to be present at Slip 4 include those adapted to urban environments, such as great blue heron, killdeer, a variety of gull species, swallows, sparrows, finches, rock doves, crows, Canada geese, belted kingfishers, spotted sandpipers, and European starlings. Windward (2003c) reported that up to 87 species of birds use the LDW at least part of the year to feed, rest, or reproduce. Fifteen bird species were observed in the waterfront park and Slip 4 area during a site visit by SEA on June 30, 2003. Bald eagles,

peregrine falcons, and osprey have been observed along the Duwamish. Aquatic species include a variety of ducks, including mallards, gadwall, scoters, goldeneyes, and scaup. Pigeon guillemots, mergansers, grebes, and cormorants may feed on small fish (Cordell et al. 1996; USACE et al. 1994; Weston 1996). It is likely that these species would use Slip 4 primarily for resting and feeding, as nesting habitat and cover are limited.

The highly developed land use surrounding Slip 4 makes most of the area unsuitable for many terrestrial mammals, but the small park on the southeast side of Slip 4 may provide some habitat for terrestrial wildlife. Various small mammals that inhabit urban habitats could be present, including rabbits, opossums, mice, shrews, moles, bats, squirrels, muskrats, and raccoons. There are river otters in the lower Duwamish at Kellogg Island, but lack of suitable habitat makes it unlikely that this species would be found at Slip 4.

The Duwamish River provides habitat for several species of marine mammals that could enter Slip 4, although this is unlikely. Harbor seals and sea lions have been sighted in the Duwamish River corridor. Harbor seals were observed in the vicinity of Slip 4 in the fall of 2003 (Cummings 2004, pers. comm.). The nearest haulouts to Slip 4 are located on Harbor Island. Steller sea lions and killer whales have been observed in Elliott Bay but there is no record of these species entering the Duwamish. Similarly, Dall's porpoise are present in the outer bay south of West Point, and minke and gray whales are occasionally reported in Elliott Bay, but these species are unlikely to enter the Duwamish.

Threatened and Endangered Species

Fifteen fish and wildlife species observed in the LDW are listed under the federal Endangered Species Act (ESA) and/or by WDFW as threatened, endangered, candidate species, or species of concern (Table 2-2). Windward (2003c) reports that except for chinook salmon, coho salmon, bull trout, bald eagle, western grebe, and perhaps Pacific herring, use of the LDW by these listed species is rare or incidental. Only one of these species, chinook salmon, is confirmed to be present in the immediate vicinity of Slip 4.

The Natural Heritage Program indicated that they have no records of rare plants, high-quality native wetlands, or native plant communities in the vicinity of Slip 4 (SEA 2004). No special aquatic sites or priority habitats are listed by WDFW for Slip 4, other than the classification of all the lower Duwamish as estuarine habitat (SEA 2004).

2.2 REGULATORY HISTORY

2.2.1 Previous Environmental Investigations

Numerous historical environmental investigations have included the collection of sediment data in Slip 4. Four sediment investigations were conducted in Slip 4 between 1990 and 1999. These investigations included an EPA site investigation (Weston 1999), a NOAA sediment characterization of the Duwamish River (NOAA 1998), a site assessment

(Landau 1990), and a dredged material characterization (Exponent 1998). Results of these investigations are summarized in Section 2.3.1 of this report, and the resulting data were described in detail by SEA (2004).

Additional characterization data were collected in Slip 4 in 2004 (Integral 2004a). The initial investigation in April 2004 included collection of surface sediment samples at 29 locations, subsurface cores at 11 locations, and one intertidal composite sample. Bank samples were collected at six locations in July 2004. These investigations are summarized in Section 2.3 of this report and are described in detail by Integral (2004a).

Previous upland investigations adjacent to Slip 4 have included soil and groundwater sampling. These investigations were generally conducted as part of site assessments during property transfers, in conjunction with underground storage tank removal, or during construction when visible contamination (e.g., petroleum-staining) was observed or excavated soil required testing prior to disposal. A Resource Conservation and Recovery Act (RCRA) corrective action is being conducted at Boeing Plant 2. These investigations are also described in SEA (2004).

Additional bank soil and sediment data were collected in 2005 (Parametrix 2005; CH2M Hill 2005a; Bach 2005a, pers. comm.) and are summarized in this EE/CA. These data are used in this EE/CA to refine the boundaries of the removal action [the preliminary boundaries are described in the *Revised Draft Technical Memorandum on Proposed Boundary of the Removal Action* (Integral 2005), which is contained in Appendix A].

2.2.2 Previous Removal Actions

There have been no previous removal actions or sediment cleanup activities in Slip 4. However, sediments in the slip have been dredged. Known dredging events were in 1981 and 1996 when sediments on the west side of the slip were removed to allow ship and barge access to the berthing area (see Section 2.1.2). Dredged material removed in 1981 was disposed of at the Four Mile Rock disposal site in Elliott Bay. Approximately 25 percent of the sediments removed in 1996 were disposed of at a Puget Sound Dredged Disposal Analysis (PSDDA) open-water disposal site in Elliott Bay, and the remaining sediment was disposed of at an upland location because of elevated chemical (primarily PAHs and PCBs) concentrations (USACE 1996).

2.3 SUMMARY OF ENVIRONMENTAL DATA

2.3.1 Sediment Quality Data

Existing environmental data provided the basis for determining the removal action boundary. Historical data (1990–1999) were compiled, and additional data were collected in 2004 to fill data gaps. This information was previously presented by SEA (2004) and

Integral (2004a), and new information from Parametrix (2005), CH2M Hill (2005a,b), and Bach (2005a, pers. comm.) is also presented below.

All chemical data were compared to the Washington State Sediment Management Standards (SMS). These include both the SQS and CSL (WAC 173-204) (Table 2-3). Sediments that meet the SQS criteria have a low likelihood of adverse effects on sediment-dwelling biological resources. The initial designation under the SQS is based on comparison with numerical criteria, and these criteria are used in this evaluation of existing data. However, an exceedance of the SQS numerical criteria does not necessarily indicate adverse effects or toxicity, and biological testing may be used to confirm the initial designation regardless of chemical concentration. Additionally, the degree of SQS exceedance does not correspond to the level of sediment toxicity. The CSL or minimum cleanup level (MCUL) is defined as the maximum allowed chemical concentration and level of biological effects permissible at a cleanup site to be achieved by year 10 after cleanup has been completed. The CSL is greater than or equal to the SQS and represents a higher level of risk to benthic organisms than SQS levels. The SQS and CSL values provide a basis for identifying sediments that may pose a risk to some ecological receptors, and are thus useful for identifying sediments that may pose unacceptable risks.

The SMS for organic chemicals (excluding ionizable organic compounds) are based on total organic carbon (TOC)-normalized concentrations. For lower Duwamish River sediments, the recommended lower limit for carbon-normalization is 0.2 percent TOC (Michelsen 1992). Organic chemical results from the samples with less than 0.2 percent TOC were not carbon-normalized but were instead compared to dry-weight AET values (PTI 1988).

2.3.1.1 1990–1999 Sediment Investigations

The surveys conducted between 1990 and 1999 included collection of surface sediment samples at 41 sampling locations and subsurface sediment cores (up to 10 feet deep) at 12 locations in Slip 4. The results are described in the *Summary of Existing Information and Identification of Data Gaps* report (SEA 2004).

The results for surface sediments are shown in Figures 2-6 and 2-7. The data confirmed that PCBs are the contaminant of primary concern in Slip 4 surface sediments due to their areal extent and concentrations. PCBs exceeded the SQS at nearly all surface sampling locations; over half the locations exceeded the PCB CSL (Figure 2-6, Table 2-4). The highest PCB concentrations were at the head of the slip, and concentrations decreased toward the mouth. There was only one historic sampling location (SL4-12) where detected chemicals other than PCBs exceeded the SQS but PCBs did not exceed the SQS.

Other chemicals exceeding the SQS or CSL in surface sediments included metals and PAHs in samples located in the vicinity of the outfalls at the head of the slip (Figure 2-7). Bis(2-ethylhexyl)phthalate (BEHP) exceeded the SQS and the CSL at some stations.

In subsurface sediments, PCBs were also the contaminant with the most frequent SQS exceedances; these results are presented in Figure 2-8. The maximum depth of PCB SQS exceedances ranged from 4 feet to greater than 9 feet. CSL exceedances below 4 feet were observed in only 2 of the 10 cores (i.e., Stations SL4-6A and SL4-10A). At both locations with CSL exceedances below 4 feet, PCBs were the only detected chemical exceeding the CSL at depths greater than 4 feet, and the maximum depth of PCBs exceeding the CSL was greater than 8–9 feet. In the historical data set, PCB concentrations in sediments tended to decrease with depth. In the 2004 data set, PCB concentrations in surface (0–10 cm) or shallow subsurface (0–2 foot) intervals are generally less than the PCB concentrations in the immediately underlying intervals.

Only two detected chemicals other than PCBs (i.e., acenaphthene and fluoranthene at SL4-06A and SL4-09A) exceeded the SQS in subsurface sediments below 2 feet (SQS exceedance factors 1.06–2.88) [see Figure 5-14 in SEA (2004)].

2.3.1.2 2004 Sediment Investigations

Surface and subsurface sediment chemistry data were collected in 2004 to fill data gaps and allow delineation of the removal action boundary. Surface (0–10 cm) sediment samples were collected at 29 locations, an intertidal composite sample was collected along the south shore, sediment cores (maximum depth of 12 feet) were collected at 11 locations, and bank samples were collected at six locations.

Sample analyses were tiered. PCB Aroclors and mercury were analyzed in all samples. The other SMS analytes were analyzed in a subset of samples from areas likely to be outside the boundary, as well as at a quality control (QC) station in the upper portion of the slip. The rationale for selection of samples for SMS analysis is provided by Integral (2004e).

PCB Results

Surface Sediment. PCB concentrations in surface sediment and bank samples collected in 2004 are reported as both dry-weight and carbon-normalized concentrations (Figures 2-9 and 2-10, respectively). Concentrations are compared to SMS values in Figure 2-10 and Table 2-5.

PCB concentrations in 2004 exceeded the SQS at six stations (and one field replicate station) (Figure 2-10). CSL exceedances were confined to three stations at the head of the slip and the intertidal composite sample (IC-01) located along the eastern bank of the slip. Total PCBs at the remaining 20 surface sediment stations were below the SQS.

Subsurface Sediment. Of the 11 stations where subsurface cores were collected in 2004, samples from nine stations were analyzed by either the City of Seattle/King County or The Boeing Company. (Samples from Stations SC08 and SC10 remain archived.) Dry-

weight and carbon-normalized PCB concentrations are shown in Figures 2-11 and 2-8, respectively, and are listed in Table 2-5. Six of the nine cores that were analyzed contained one or more intervals with PCBs greater than the CSL. At these stations, CSL exceedances commonly occurred to a depth of 4 or 6 feet. At most locations, no SQS exceedances occurred below 4–6 feet, although CSL exceedances occurred in the 8- to 10-foot interval at Station SC-02 and in the 6- to 8-foot interval at Station SC-03. The depth of sediments exceeding SQS was bounded in all cores except SC-02. An archived sample from the 10- to 12-foot interval at SC-02 may be analyzed, if needed for design purposes.

Other Chemical Results

Surface Sediment. For the subset of 2004 samples that were analyzed for other SMS analytes, eight subtidal samples were analyzed for all SMS organic compounds; four of these eight samples were also analyzed for all SMS metals (Figure 2-12) (Integral 2004e). Two additional samples (i.e., samples SG06 and SG06FR) were analyzed for all SMS organics and metals because they were field QC samples. The intertidal composite sample (IC01) was also analyzed for all SMS analytes. Except for the field QC samples, only one of these locations (SG16) had detected chemicals other than PCBs at concentrations greater than the SQS (however, PCBs also exceeded the SQS at this location) (Figure 2-10). At Station SG16, BEHP and phenol, as well as PCBs, were slightly above the SQS. In the field QC samples [SG06 and SG06FR (SG41S)], two organic chemicals, as well as PCBs, were greater than the SQS or CSL (Figure 2-12). No other metals or organic chemicals exceeded the SQS.

Subsurface Sediment. Other detected chemicals that exceeded the SQS or CSL in subsurface sediment included mercury (seven samples with exceedances) and silver (one sample) (Table 2-6). All metals exceedances were in samples that also had PCBs greater than the SQS or CSL except for the 6- to 8-foot interval at Station SC04. Other than PCBs, there were no detected organic chemicals in subsurface sediment samples that exceeded the SQS or CSL (Integral 2004a).

Comparison of Historical and 2004 PCB Results

When the surface PCB concentrations from 2004 are compared with historical data collected between 1990 and 1998, it is evident that PCB concentrations in surface sediments in many areas of the slip are less in 2004 than they were between 1990 and 1998 (Figures 2-6 and 2-12). In addition, the 2004 collocated surface (surface to 10 cm) and subsurface sample results can be compared (Figure 2-8). In all cases, total PCBs in the surface sample are less than the concentrations in the top interval (0–2 feet) of the collocated core. These decreasing PCB concentrations over time and throughout the slip may be the result of reduced PCB input due to source control, and physical processes

consistent with natural recovery (e.g., sedimentation, dispersion, dilution, bioturbation), within Slip 4.

2.3.1.3 Physical Sampling and Testing of Sediments

Grain-size data for Slip 4 sediments were collected in both historic and recent investigations. Surface sediments sampled in 2004 ranged from less than 10 percent to over 80 percent fine material (i.e., clay and silt). The coarsest sediment was found along the east side and at the head of the slip. These are areas that have not been dredged or are located near outfalls. Subsurface sediment grain size also varied widely, consisting of 1.8–91 percent fines.

Sediment samples for physical testing were collected at all surface and subsurface locations sampled in 2004. These samples are currently archived. A subset of these samples may be selected for analysis of physical parameters (e.g., bulk density, Atterberg limits) as needed for design of the selected removal action remedy.

2.3.2 Upland Soil Quality

2.3.2.1 1989 to 2004 Upland Investigations

Data for upland soils adjacent to Slip 4 were collected in the late 1980s and early 1990s by property owners as part of site assessments, underground storage tank removals, or construction/excavation projects (SEA 2004). Chemical concentrations in soils were most commonly compared to MTCA Method A criteria to evaluate the data and determine cleanup requirements. Total petroleum hydrocarbons (TPHs), metals (primarily arsenic, but also cadmium and lead), and PAHs were the contaminants most commonly exceeding MTCA criteria. PCB concentrations were generally lower than the MTCA Method A criteria for industrial properties (10 mg/kg), with reported concentrations ranging from undetected to 14 mg/kg. Contaminated soils have been removed from First South Properties and Boeing. First South Properties received *No Further Action* (NFA) status for TPH from Ecology in 1997, contingent on restrictive covenants. Additional information and more detailed summaries of pertinent upland soil investigations are provided in SEA (2004). Results of recent bank soil/sediment sampling are presented in Section 2.3.3.4.

2.3.2.2 2005 Upland Investigations

In 2005, upland soil samples were collected at First South Properties by Emerald Services and Ecology. In addition, SPU collected a soil sample from a drainage area at First South Properties as part of their Slip 4 source control investigations. These three sampling investigations are described below, and sampling locations and results are shown in Figure 2-13.

Emerald Services, the current occupant at First South Properties, collected upland soil samples for PCB analysis in April 2005 (CH2M Hill 2005a,b). First, seven surface (0–10 cm) soil samples (FS01-BK02 through FS07-BK06) were collected approximately 10 to 20 feet inland from the top of the bank. Second, surface soil samples (FS-D1 and duplicate) were collected in a drainage area where stormwater runoff from First South Properties has the potential to transport upland surface soil to Slip 4.² Third, a subsurface sample (FS-P1) was collected near the center of the site. This subsurface sample was reported to be native soil just below the fill material.

Results of the Emerald Services surface and subsurface soil analyses are shown in Figure 2-13. Concentrations of PCBs in surface soils along the top of the banks ranged from undetected to 6.2 mg/kg OC (143 µg/kg DW). All concentrations were less than the SQS. If PCB concentrations in surface soil from the drainage area (FS-D1 and duplicate) are normalized to organic carbon for comparison to sediment standards, PCBs in the two samples ranged from 23 mg/kg OC to 810 mg/kg OC, respectively (the first greater than the sediment SQS of 12 mg/kg OC and the second greater than the sediment CSL of 65 mg/kg OC). PCBs were undetected in the subsurface native material in the center of the site.

In 2005, Ecology also collected soil samples at 10 upland boring locations and at the drainage area at First South Properties (Parametrix 2005; Elkind 2005, pers. comm.).³ All samples were analyzed for PCBs. The sampling locations and detected PCB results are shown in Figure 2-13. Ecology's surface soil sample from the drainage area (BS-07) contained PCBs at 6.1 mg/kg OC (197 µg/kg DW) and was less than the SQS.

PCBs were detected in subsurface soil samples from four of the 10 upland borings sampled by Ecology at First South Properties near the Slip 4 shoreline (Figure 2-13). Along the northern half of First South Properties' shoreline, PCBs were detected at concentrations above the SQS in subsurface samples from SB-1, SB-3, and SB-4, at depths ranging from 2 to 11.5 feet bgs. On the southern half of First South Properties shoreline, PCBs were detected at a concentration slightly above the SQS in one shallow subsurface (0–1.5 feet bgs) soil sample at SB-11 (located above bank station BK-06). Dry-weight concentrations were all below evaluation criteria for upland soils [i.e., the MTCA Method A criteria for industrial properties (10 mg/kg DW)]; however the samples noted above

² The laboratory analyzed each sample for PCBs twice, and results varied substantially. Because all quality assurance / quality control (QA/QC) requirements were met in both analyses, both sets of data were reported to Emerald Services (CH2M Hill 2005b) and are included in this summary.

³ Sampling intervals shown in Figure 2-13 are based on boring logs contained in Parametrix (2005). Parametrix (Elkind 2005, pers. comm.) confirmed discrepancies in the report and stated that the "extent" column in the boring logs indicates the correct sample depths.

exceeded SQS and could pose risks in the marine environment if they become exposed by erosion.

Ecology's (2005) determinations regarding these data were summarized as follows:

Based on the sampling results, Ecology has determined that active cleanup at Slip 4 Upland is not necessary at this time. It does not appear that there is any major on going upland PCB contamination source existing on site. Ecology will work with the City of Seattle to address the surface and subsurface bank soil/sediment PCB contamination at the time when the City is conducting sediment clean up in Slip 4. A cap may be required after the City stabilizes the bank as part of the sediment cleanup in Slip 4.

As described in Section 3, the scope of the Slip 4 removal action includes removal/stabilization/containment actions to ensure that bank soils do not recontaminate Slip 4 sediments.

Finally, SPU collected one surface soil sample at S-1 from the drainage area to Slip 4 (Figure 2-13). All SMS chemicals were analyzed. PCBs were undetected. BEHP (177 mg/kg OC) was the only chemical reported above the CSL (78 mg/kg OC). No other chemicals exceeded the SQS or CSL. Additional information on the SPU sampling results is provided in Section 2.6 and Appendix B.

2.3.3 Potential Source Data

Existing data for groundwater, seeps, stormwater discharges, and banks adjacent to Slip 4 are briefly described in the following sections.

2.3.3.1 Groundwater

Existing groundwater data collected on upland properties adjacent to Slip 4 in 1989–1996 are reported in the *Summary of Existing Information and Identification of Data Gaps* report (SEA 2004). These investigations and chemical analyses are summarized in Table 2-7. As shown in Table 2-7, groundwater conditions adjacent to Slip 4 were evaluated as part of environmental site assessments of the First South Properties and Crowley sites, as well as in association with removal of several underground storage tanks (USTs) and associated TPH-contaminated soil at Boeing. Several of the test holes and monitoring wells completed during these studies were located near the bank of Slip 4. Analytical parameters included volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), TPHs, PAHs, PCBs, and selected metals.

Groundwater sampling locations at First South Properties and Crowley are shown in Figures 2-14, 2-15, and 2-16. For the purpose of evaluating potential effects of

groundwater as it discharges to Slip 4 surface water, these figures also depict analytical results where chemicals in groundwater exceeded surface water quality criteria. A number of constituents were detected in the soil, several of which exceeded applicable MTCA cleanup standards (including, but not limited to, TPH, cadmium, lead, and chromium). In addition, arsenic, copper, and zinc were detected in groundwater at concentrations exceeding marine chronic surface water quality criteria. However, chemicals that were elevated in groundwater were not reported at concentrations greater than the SQS in Slip 4 sediment samples nearest the groundwater sampling locations. TPHs, VOCs, and LPAHs were also detected in groundwater, but at relatively low concentrations. PCBs were not detected in any of Landau's 1990 soil or groundwater samples or in the Crowley site assessments.

Removal of the USTs effectively reduced TPH concentrations on the First South Properties and a conditional NFA determination was issued by Ecology in 1997. Subsequent groundwater monitoring verified compliance with the applicable cleanup requirements, and Ecology determined that all conditions of the NFA had been met (Ecology 1998).

At Boeing Plant 2 near the Slip 4 shoreline (and south of the EAA), groundwater samples were collected from six push-probe borings. Vinyl chloride (2.0 µg/L) was the only VOC detected in groundwater; the detected concentration was well below the water quality criterion for human consumption of aquatic organisms (525 µg/L). Chromium (up to 11 mg/L), copper (2.7 mg/L), lead (0.7 mg/L), nickel (3.8 mg/L), and zinc (2.4 mg/L) were the only metals detected in groundwater. All of these metals were detected in one or more samples at concentrations that exceeded their respective marine chronic water quality criteria. However, it is important to note that the marine chronic water quality criteria are based on concentrations of dissolved metals rather than total metals (i.e., includes both dissolved metals and metals associated with particulate material in the water). The Boeing groundwater samples collected using push-probe sampling methods were typically turbid and were not representative of ambient dissolved metals concentrations in groundwater. Therefore, comparison of metals concentrations in these turbid samples to the dissolved metals criteria is extremely conservative. Oil and grease was detected in several groundwater samples at concentrations ranging from 0.8 to 12 mg/L (Weston 1990).

Boeing performed a Release Assessment under an AOC for a 3008(h) RCRA corrective action (Weston 1994). The assessment included an evaluation of groundwater quality data from the north end of Plant 2 in the vicinity of Slip 4. The full suite of groundwater analytes is not known. Arsenic (up to 30 mg/L) and chromium (up to 60 mg/L) were detected in unfiltered groundwater samples collected from the wells (Weston 1994). The maximum detected metals concentrations exceeded their respective marine chronic water quality criteria. Metals, including arsenic and chromium, were not found at concentrations above the SQS in Slip 4 sediments near Boeing.

In summary, the existing groundwater data from wells nearest the shore adjacent to the Slip 4 EAA support the conclusion that groundwater is not a significant source to sediments in the Slip 4 EAA. These conclusions are currently being evaluated by Ecology and are addressed in the *Lower Duwamish Waterway Source Control Action Plan for the Slip 4 Early Action Area* (Ecology 2006).

2.3.3.2 Seeps

During periods of low tides, surface water seeps can be observed in lower intertidal areas of Slip 4. These seeps may include both groundwater discharge from nearby uplands as well as drainage of saturated nearshore fill material. One of the seeps (Seep 10, Figure 2-10) on the east side of Slip 4 was sampled by Windward (2004b). The sample was filtered to remove particulate material and analyzed for metals, VOCs, SVOCs, PCBs, and pesticides. This seep is located in the bank area where the highest PCB concentrations were found, and likely represents the area of greatest concern for transport of chemical contaminants to Slip 4. PCBs were undetected in the water sample from Seep 10. The concentration of one metal, copper (8.69 $\mu\text{g/L}$), was greater than the acute and chronic marine water quality criteria (4.8 and 3.1 $\mu\text{g/L}$, respectively). However, this result was qualified as an estimate because copper was detected in the rinsate blank and concentrations (including reporting limits for nondetects) exceeded the water quality criteria at all 18 seeps sampled in the LDW in this investigation. All other chemicals in the sample from Seep 10 were undetected or less than water quality criteria.

Together with the groundwater data, the seep data support the conclusion that groundwater is not a significant source to Slip 4 sediments.

2.3.3.3 Discharges

Most data from Slip 4 point discharges are historic and were collected in the 1980s. Metro (1985) and Tetra Tech (1988a) identified the flume as a historic source of PCBs and North Boeing Field SD as a historic source of PCBs and other chemicals [see Tables 3-3 and 3-4 in SEA (2004)]. Seattle City Light (SCL) collected numerous sediment samples in the flume between 1985 and 1991. Following closure of all known, unpermitted connections to the flume in 1987, PCBs ranged from 0.25 to 14.26 mg/kg. Quarterly monitoring was conducted from 1989 through 1991. Boeing sampled sediments in its stormwater collection system discharging to the flume in 1992; PCB concentrations ranged from 0.094 to 426 mg/kg (Wilson 1993) and 5.1 to 160 mg/kg (Landau 1993). The sampling was followed by a major storm drain cleanout that included removing sediment from approximately 90 percent of the manholes, 81 percent of the catch basins, and 60 percent of the piping (Landau 1993). Flume sediment sampling was conducted in 1998 (HWA 1998); PCB concentrations ranged from undetected to 3.9 mg/kg.

New data from the discharges to Slip 4 were collected in 2004-2005 in conjunction with ongoing source control activities and are summarized in Appendix B.

2.3.3.4 Bank Soil

2004 Data

Six bank samples were collected in 2004 at +10 feet MLLW along unarmored sections of the Slip 4 shoreline (Integral 2004a). PCBs at four sampling stations along the east shoreline (BK-02, BK-03, BK-04, and BK-05) exceeded the SQS, and one station (BK-06) exceeded the CSL (Figure 2-10). PCBs in sample BK-01, located west of the outfalls near the head of the slip, were below the SQS. Previous upland investigations have characterized the stratigraphy of soils near the Slip 4 embankments (Landau 1990). These soil borings indicate that fill material overlies native tideflat and river deposits. In the vicinity of the east shoreline, where bank samples exceeded the SQS at +10 feet MLLW, the fill/native interface generally occurs at elevations ranging from +4 to +11 feet MLLW. Therefore, the bank samples collected in this investigation may represent fill material or some mixture of fill material and sedimentary deposits. Field observations by the sample collectors noted possible fill material in bank samples.

Intertidal sediments (Station IC01) below the bank in the vicinity of Station BK06 also contained PCBs at concentrations exceeding the CSL. Sediments exhibiting elevated PCBs in this localized intertidal area are likely being impacted by eroding fill from the bank.

2005 Data

As a result of the elevated PCB concentrations reported for bank samples collected in 2004, additional bank sampling was conducted in 2005 by Ecology (Parametrix 2005) and Boeing (Bach 2005a, pers. comm.). Ecology collected samples along the southeast shoreline at First South Properties. Boeing collected three samples in the immediate vicinity of Station BK-06, where PCBs in a 2004 sample had exceeded the CSL. Results of these sampling events are shown in Figure 2-17 and briefly described below. Additional upland soil samples were also collected and are discussed in Section 2.3.2.2.

Ecology collected surface samples at the toe or base of the bank slope (sample prefix "BB" in Figure 2-17) and subsurface samples at the midpoint of the bank slope (sample prefix "BS" in Figure 2-17). PCB concentrations in all six of the toe-of-bank surface samples exceeded the SQS; two of these samples also exceeded the CSL (BS-01 and BS-05). The subsurface (1.5–3 feet bgs) bank soil samples were collected at the midpoint of the bank, PCBs in four of the six subsurface bank samples exceeded the CSL (Parametrix 2005).

Boeing collected additional surface sediment and asphalt samples from the bank at BK-06 and within a few feet of BK-06 (Bach 2005a, pers. comm.). PCB concentrations in soil were above the SQS in two of the three soil samples (Figure 2-17). PCBs were detected in the asphalt samples but concentrations were less than in nearby soil.

2.4 STREAMLINED RISK EVALUATION

EPA guidance for conducting an EE/CA requires a streamlined risk evaluation. The streamlined risk evaluation is "...intermediate in scope between the limited risk evaluation undertaken for emergency removal actions and the conventional baseline assessment normally conducted for remedial actions" (USEPA 1993). The streamlined risk evaluation is designed to evaluate risks occurring from potential exposure pathways if no cleanup action is taken at the site. The results help determine whether a cleanup action should be taken and what exposures need to be addressed. The streamlined risk evaluation addresses only the specific sources of contamination and focuses on the specific problem that the removal action is intended to address (USEPA 1993). Therefore, for Slip 4, the streamlined risk evaluation addresses risk only from exposure to contaminated sediments in the absence of a removal action.

EPA guidance for a streamlined risk evaluation states that where standards for one or more contaminants in a given medium are clearly exceeded, a removal action is generally warranted and further quantitative risk assessment of multiple chemical exposure is generally not necessary (USEPA 1993). Consistent with this approach, a quantitative risk assessment is not considered necessary for the Slip 4 EAA.

Areas in the LDW outside of the Slip 4 removal action boundary will continue to be evaluated by the LDWG, EPA, and Ecology under the LDW RI/FS. The LDW RI/FS will include a baseline ecological and human health risk assessment to evaluate potential risks to human health and the environment posed by sediments in the LDW site.

2.4.1 Exposure Pathways

Potential exposure pathways for ecological and human receptors are described in this section based on the site usage information provided in Sections 2.1.7 and 2.1.8 and by Windward (2003c).

Ecological receptors include benthic organisms, fish, birds, and mammals. Potential exposure pathways for benthic organisms include direct contact with contaminated sediment or interstitial water associated with contaminated sediment, and ingestion of contaminated sediment. The primary potential exposure pathway for mammals, birds, and fish is ingestion of marine organisms. Bottomfish may have additional exposure due to direct contact with or ingestion of contaminated sediment.

The primary human exposure pathways to Slip 4 sediments are both direct and indirect. Direct exposure to contaminated sediment may occur to fishers who contact sediment incidentally during gear retrieval or shellfishing, or from suspended sediment in the water. While exposure pathways are similar for both tribal and recreational fishers, overall risk in the absence of any sediment removal action may be higher for tribal fishers compared to recreational users due to potentially more frequent exposure and/or higher

ingestion rates of fish and shellfish. Boaters (primarily small boats or paddlers) may also directly contact contaminated sediments by accessing intertidal areas at low tide. Indirect human exposure to contaminants may occur from ingestion of fish or shellfish that are in contact with sediment or that have fed on prey that reside within the sediment.

2.4.2 Risk Characterization

2.4.2.1 Ecological Risk

Ecological risk to benthic communities in Slip 4 is evaluated through comparison with the SMS numerical chemical concentration criteria. The SMS numerical criteria are based on the results of sediment toxicity tests and benthic infauna analyses. The SMS are considered protective of benthic organisms and are comprised of two types of numerical criteria—SQS and CSLs. Concentrations of contaminants equal to or less than the SQS are unlikely to have adverse effects on biological resources in Puget Sound marine sediments. An exceedance of the SQS numerical criteria indicates the potential for minor adverse biological effects or toxicity. The CSL is greater than or equal to the SQS and represents a higher likelihood of risk to benthic organisms than SQS levels.

Surface (the 0–10 cm biologically active sediment layer) sediment chemistry data from Slip 4 were used to estimate risks to benthic infauna if no cleanup takes place. The sediment chemistry data were described and compared to the SMS in Section 2.3.1. In surface sediment data collected in 2004, PCB concentrations exceeded the CSL at three of 29 sample locations and in the intertidal composite sample. PCB concentrations at six additional sampling locations exceeded the SQS. The only other detected chemicals that exceeded the SQS or CSL in the 2004 surface samples were BEHP, phenol, and indeno[1,2,3-c,d]pyrene. CSL exceedances of these three chemicals are included within the proposed removal area. There are slight exceedances of the SQS for phenol (exceedance factor = 1.14) and BEHP (exceedance factor = 1.08) at one location outside the proposed boundary. Under the provisions of the SMS, chemical concentrations within the proposed removal boundary that exceed the SQS have the potential to cause minor adverse effects, and PCB concentrations that exceed the CSL have a greater potential to result in adverse effects. Surface sediments within much of the proposed removal boundary area significantly exceed SMS standards, indicating that these sediments may pose a risk to benthic community health if no cleanup action is taken.

Risks to other potential ecological receptors in Slip 4 are evaluated in the context of the LDW. Larger organisms such as birds, fish, and mammals are mobile and could be exposed to chemicals in sediment throughout the LDW, including Slip 4. Initial evaluations of risk from sediment to fish and wildlife species that may reside or forage in the LDW for at least part of their lives were conducted as part of the Phase 1 Ecological Risk Assessment (ERA) for the LDW RI (Windward 2003c). The results of this assessment

are very briefly summarized here; additional detailed information is provided in the original report by Windward (2003c).

The Phase 1 ERA evaluated risks to representative fish and wildlife species from exposure to chemicals in LDW sediments. This assessment is summarized in Table 2-8.

Representative species selected for the ERA included benthic invertebrates, crabs, English sole, great blue heron, spotted sandpiper, bald eagle, river otter, harbor seal, and aquatic-rooted plants. Wild juvenile chinook salmon and bull trout were also evaluated because they are federally listed species with complete exposure pathways in the LDW (Windward 2003c).

Species in the LDW are exposed to sediment contaminants either directly through exposure to sediments or indirectly through consumption of other species. Therefore, existing sediment, tissue, and porewater data were all used in the Phase 1 ERA. Chemicals of potential concern for each species of concern were screened by comparing exposure data (either tissue body burden data or from estimated dietary exposure doses) to effects data (obtained from the scientific literature) to assess if there was a potential adverse effect. Assessments of exposure and risk were conservatively biased.

Results of the Phase 1 ERA indicated that PCB exposure concentrations were greater than concentrations associated with adverse effects for fish and great blue herons (based on egg data). Arsenic and copper were associated with adverse effects in fish. Other chemicals with exposure estimates greater than no-effects levels but less than the adverse-effects level for one or more fish or wildlife species included PAHs, mercury, tributyltin (TBT), lead, and arsenic (Windward 2003c). The Phase I ERA was a screening-level approach intended to guide the planned baseline risk assessment. The actual risk characterization for pathways and receptors of concern will be accomplished in the Phase 2 (baseline) ERA for the LDW.

2.4.2.2 Human Health Risk

Risks to human health from sediments in Slip 4 are also evaluated in the context of the overall LDW via the Phase 1 Human Health Risk Assessment (HHRA) prepared by Windward (2003c). The Phase 1 HHRA evaluated risk using existing data; the risk assessment will be revised in Phase 2 to incorporate new data and address uncertainties in the Phase 1 HHRA. The Phase 2 HHRA will also estimate risk from sediment remaining in the LDW following completion of the early action site cleanups.

The Phase 1 HHRA identified and evaluated three primary routes for human exposure to chemicals in LDW sediments:

- Contact with sediment during commercial netfishing (adults)
- Contact with intertidal sediment during beach play (children)

- Consumption of fish and shellfish (tribal and Asian and Pacific Islander adults and children).

King County (1999) quantified risks associated with surface water contact (i.e., swimming) in the Duwamish River and Elliott Bay. Swimming risks were in the 1 in a million range and were 2 orders of magnitude lower than risks posed by seafood consumption. They concluded that risks from this exposure were well within acceptable levels identified by EPA.

Windward (2004c) surveyed clams and clam harvest in the LDW. Windward's results indicate that harvestable numbers of clams are present in the LDW. The Phase 1 risk assessment (Windward 2003c) did not examine direct contact exposure for individuals engaged in clam harvest, but this will be done in the Phase 2 risk assessment.

Some exposure routes of the three scenarios identified for the LDW are less likely to occur in Slip 4 due to limited access (i.e., beach play). In addition to their slightly different exposure scenarios, the chemical concentrations and exposure duration and frequency in Slip 4 likely differ from the LDW as a whole. However, given that people are mobile, their most reasonable exposure is to sediment throughout the LDW. Therefore, the results of the Phase 1 HHRA for the LDW are summarized in this section. Additional detailed information can be found in the original report by Windward (2003c).

LDW Phase 1 Human Health Risk Assessment

In the Phase 1 HHRA, risks from the three exposure scenarios above were evaluated using surface sediment and tissue (edible crab meat, English sole filets, perch filets, and mussels) chemistry data collected prior to 2003. Chemicals were screened by Windward (2003c) using EPA guidance to identify chemicals of potential concern (COPCs) in sediment. Forty-three chemicals were identified as COPCs for one or more of the three exposure pathways; 22 of these were not detected in sediment or tissue but were included because their detection limits were above risk-based concentrations.

Exposure was determined for each of the three scenarios by calculating chemical intake based on chemical concentrations and the frequency and duration of exposure. Reasonable maximum exposure estimates were calculated for each scenario using high-end but plausible estimates of exposure. As a result, risks were conservatively estimated to assure site management decisions that are protective of all individuals who may be exposed. Data from numerous sources and other risk assessments and reports were used. Data provided by the Muckleshoot Tribe were used to determine exposure by direct contact while netfishing. Exposure duration and frequency during beach play was determined based primarily on EPA guidance and on best professional judgment since site-specific data were not available. The seafood consumption exposure values were

based on data collected by the Suquamish Tribe and additional data for Asian and Pacific Islanders.

The toxicity of each chemical was based on EPA values from laboratory tests or epidemiological studies. Chemical concentrations in sediments at the point of exposure were determined using site-specific chemical data for the area within the LDW over which the exposure could occur. For example, people netfishing may be exposed to both subtidal and intertidal sediments throughout the LDW, while children engaged in beach play could only be exposed to intertidal sediments. Seafood chemical concentrations were determined using separate chemistry data and consumption rates for each species, then chemical intake rates for each of the consumed species were summed to provide an overall chemical intake for evaluating risk.

The Phase 1 HHRA included separate evaluations of carcinogenic risks and noncarcinogenic health effects. Both carcinogenic and noncarcinogenic risk estimates were highest for the seafood consumption scenario. The fish and shellfish consumption risk estimates exceed the upper end of EPA's target carcinogenic risk range of 10^{-4} to 10^{-6} . Cancer risks from netfishing and beach play (less than 1 in 100,000) were substantially lower than for seafood consumption (cumulative risk for all carcinogenic chemicals for the adult tribal fish consumption scenario was 2 in 1,000). PCBs, carcinogenic PAHs, and arsenic were the primary contributors to cumulative cancer risk from all pathways.

For noncarcinogenic health effects, arsenic, PCBs, TBT, and mercury all had hazard quotients (i.e., ratio of the estimated chemical intake to the critical chemical dose) greater than 1 (Windward 2003c). This result indicates a potential adverse health effect(s) other than cancer due to consumption of fish and shellfish from the LDW.

Human Health Risk Information Specific to Slip 4

As described above, the three possible exposure routes in Slip 4 include netfishing, beach play, and seafood consumption. To provide some indication of human health risk in Slip 4, sediment concentrations were compared to human health risk-based screening concentrations. The maximum surface sediment concentration of each chemical in Slip 4 was compared to the sediment screening concentrations protective of direct sediment contact for individuals engaged in netfishing or beach play activities. These screening concentrations were derived in the LDW Phase 1 HHRA (Table 2-9) and used conservative values and assumptions. Results indicate that PCBs are the primary risk driver for these two exposure pathways in Slip 4. Only two other chemicals (arsenic and lead) exceed the risk-based screening concentrations, and each of these is exceeded at only one station. All the removal action alternatives described in this report to address PCB-contaminated sediments include removal or containment actions that will result in a clean sediment surface. Therefore, regardless of which alternative is selected, nearly all human health concerns associated with these exposures will be eliminated.

Risks due to shellfish consumption will be evaluated in the LDW Phase 2 HHRA. The LDW clam surveys in 2003–2004 indicated that clams are found in Slip 4, although at lower numbers than in other parts of the Duwamish. Windward (2004d) collected clams for tissue chemistry analysis from intertidal areas at the head of Slip 4 and along the east side of the slip. Both areas are included in the proposed removal action boundary. Clams from these areas contained PCBs, metals, and PAHs (see Section 2.1.8.2). The health risk due to seafood consumption will depend on the exposure assumptions used in the Phase 2 HHRA. These exposure assumptions will be updated and will be different than those used in the Phase 1 HHRA.

Quantitative risk estimates will be made in the Phase 2 HHRA for the baseline risk assessment. There are many uncertainties associated with the Phase 1 HHRA risk estimates. These will also be addressed in the Phase 2 HHRA.

2.4.2.3 Summary and Conclusions

In summary, the streamlined ecological risk assessment compared surface sediment concentrations within Slip 4 to the SMS. PCBs, BEHP, phenol, and indeno[1,2,3-c,d]pyrene in surface sediments within the Slip 4 EAA exceed promulgated SMS standards (SQS and CSL) for protection of benthic organisms. The distributions of PCBs, BEHP, phenol, and indeno[1,2,3-c,d]pyrene that exceed the CSL criteria are included within the proposed removal action area. There is only one station outside the proposed removal boundary with slight SQS exceedances (phenol EF=1.14, BEHP EF=1.08).

The need for a removal action is further supported by the qualitative HHRA. Human health risks specific to PCBs in the Slip 4 EAA have not been calculated; however, PCBs in Slip 4 sediments contribute to potentially unacceptable human health risks associated with seafood consumption. The removal action defined in this EE/CA will eliminate the exposure pathways to PCBs in sediments within the removal area. This will lower unacceptable risks to users of Slip 4 for seafood consumption and site-wide excess risks to users of the entire site for seafood collection.

2.5 PRELIMINARY REMOVAL BOUNDARY DEFINITION

The development and rationale for the proposed boundary for the Slip 4 removal action is described in the *Revised Draft Technical Memorandum on Proposed Boundary of the Removal Action*, contained in Appendix A of this report. This memorandum was prepared and presented to stakeholders to facilitate discussions on the boundary prior to preparation of the EE/CA. Development of the preliminary Slip 4 removal action boundary focused on the areal extent of PCBs because the historical data showed that PCBs were the primary contaminant of concern (SEA 2004); however, full-suite SMS analyses were conducted and all SMS analytes were considered. All surface and subsurface sediment data were considered in developing the preliminary boundary. Recent (2004) surface sediment data were given greater weight than historical (1990–1999) surface sediment data because

present-day surface sediments throughout the slip are substantially cleaner than those collected 6 to 15 years ago (see Section 2.3.2).

The proposed boundary was generally based on comparison of chemical concentrations with the CSL and SQS. The proposed boundary is shown in Figure 2-18 and encompasses approximately 3.6 acres in the inner half of Slip 4. This area includes all extant surface (0–10 cm) sediments with chemical concentrations greater than the SQS except for one isolated station with minor SQS exceedances. The proposed subtidal removal boundary extends across Slip 4 and is defined by the edge of the engineered riprap slope (on the northwest edge of property owned by The Boeing Company) and the northern limits of 1996 dredging in front of the Crowley pier.

Within the removal area, the shoreline has been divided into five zones based on physical and chemical characteristics (Figure 2-18). Banks with elevated PCB concentrations exist along the eastern shoreline in Zones 3, 4, and 5. The banks comprise eroding, low-bank bluffs and failing or dilapidated bulkheads. These bank deposits likely include fill material that may be a historic and/or ongoing source to Slip 4 sediments.

Ecology's 2005 investigation of bank soils and nearshore upland soils led to its conclusion that no major upland PCB sources remain and that no active cleanup of the upland area was required (Ecology 2005). However, because the actively eroding fill material in Zones 3, 4, and 5 is a potential near-term source of recontamination to Slip 4 sediments, this EE/CA includes actions to stabilize and contain these banks as part of this NTCRA. Accordingly, the removal boundary definition along these banks has been modified from that presented in the *Revised Draft Technical Memorandum on Proposed Boundary of the Removal Action* (Appendix A). Similarly, engineering evaluations of under-pier sediments in Zone 1 and the Georgetown flume outfall in Zone 2 have resulted in modifications to the removal boundary. Section 3.1.2 presents the final removal boundaries for this EE/CA, along with details on the final boundary rationale for each shoreline zone.

Areas outside of the Slip 4 removal action boundary will continue to be evaluated by the LDWG, EPA, and Ecology under the LDW RI/FS.

2.6 UPLAND SOURCE CONTROL

Information on potential sources of chemicals to Slip 4 is presented in this section. The evaluation of these sources and their relative importance and significance is based on comparison of Slip 4 sources only, not areawide LDW sources.

2.6.1 Existing Potential Pathways of Concern

Potential chemical sources and transport pathways to Slip 4 were described by SEA (2004) and include:

- Groundwater discharge

- Direct discharges to the waterway (e.g., stormwater runoff from waterfront properties, spills from barges and waterfront activities)
- Stormwater runoff from upland areas that is discharged to Slip 4 via public and private storm drain systems
- Emergency overflows from sewer pump stations
- Bank erosion.

Groundwater and direct (overland) stormwater runoff are pathways of less concern for release of PCBs to Slip 4. All groundwater investigations to date have concluded that groundwater is not a significant source of contaminants to Slip 4 (see Sections 2.3.3.1 and 2.3.3.2) (Hart Crowser 1989a,b, 1990, 1996; Landau 1990). These conclusions and the significance of potential sources to Slip 4 are currently being evaluated by Ecology and are addressed in their *Lower Duwamish Waterway Source Control Action Plan for the Slip 4 Early Action Area* (Ecology 2006).

Direct (overland) stormwater runoff and spills/leaks released to the waterway from barges or waterfront activities have also been evaluated as potential pathways for transport of contaminants to Slip 4. There may be overland stormwater runoff to Slip 4 from nearshore areas at the First South Properties parcel, as well as from the trail and vegetated areas bordering the Boeing Plant 2 shoreline (Figure 2-5). First South Properties includes some unpaved areas with exposed soils. The relatively flat topography and barriers and vegetation along the top of the bank act to reduce soil transport in overland runoff from this property. The site received NFA status from Ecology following site investigations in the 1990s. Currently, the site is used for storage (e.g., portable toilets) and dispatch, and no hazardous materials are handled at the site. Trucks and other vehicles are parked onsite. Ecology conducted additional soil sampling at First South Properties in 2005 (see Section 2.3.3). They concluded that there is not a major ongoing source of upland PCB contamination in soils from this property and determined that no further upland cleanup was required (Ecology 2005). Based on these results, the current land use, and the large amount of paved area surrounding Slip 4, direct surface water runoff is not expected to represent a significant source of ongoing contamination to Slip 4.

The remaining pathways of potential concern are:

- Outfalls (storm drains and pump station emergency overflows)
- Bank erosion.

These pathways are discussed in greater detail in Sections 2.6.1.1 and 2.6.1.2. Activities to investigate and control potential sources are described in Appendix B.

2.6.1.1 Outfalls

The Slip 4 combined sewer service area encompasses about 6,200 acres, and the storm drain basin covers about 467 acres (Figure 2-19). Land use in the basin is primarily industrial/commercial, with a small amount of residential property east of I-5. There are five public and numerous private outfalls in Slip 4 (Table 2-1, Figure 2-19). The public outfalls, including both their former and current names, are listed below:

Former Outfall Name	Current Outfall Name ¹	Outfall Diameter (inches)
Slip 4 SD (117)	King County Airport SD #3/PS44 EOF	60
Slip 4 EOF/SD ²	North Boeing Field SD	24
I-5 SD	I-5 SD	72
Georgetown flume	Georgetown flume	60
East Marginal Way EOF	East Marginal Way PS EOF	36

Notes:

EOF = emergency sewer overflow

¹ Current outfall names were provided by Schmoyer (2006b, pers. comm.)

² Overflow from the Slip 4 EOF/SD was rerouted to the Slip 4 SD (117). The current outfall names reflect this change.

There are currently no storm-related combined sewer discharges (combined sewer overflows or CSOs) to Slip 4. The City and King County both maintain EOF on pump stations that discharge to Slip 4, but overflows occur infrequently (see below). Specific information regarding the public and private outfalls is provided below:

- **King County Airport SD #3/PS44 EOF.** This 60-inch outfall, which drains the northern portion of the King County Municipal Airport, encompasses a large portion of the Slip 4 drainage area (290 acres). The drainage system at the airport has been modified numerous times. In about 1985, runoff from approximately 120 acres at the north end of the airport that formerly discharged to the 24-inch North Boeing Field SD and runoff from about 1.5 acres that formerly discharged to the Georgetown flume was diverted to the 60-inch King County Airport SD #3/PS44 EOF (SEA 2004). The emergency overflow from City pump station 44 was also diverted from the 24-inch North Boeing Field SD to King County Airport SD #3/PS44 EOF. Consequently, the 60-inch King County Airport SD #3/PS44 EOF now functions as an emergency overflow for pump station 44. This City pump station, located on Airport Way South, has not overflowed in the past five years (when the City started maintaining pump station records).
- **North Boeing Field SD.** This 24-inch outfall now drains only about 3 acres on the north end of the airport and no longer functions as an emergency overflow for

City pump station 44. Until about 1976, this system was referred to as the Greeley Street sewer and functioned as a raw sewage outfall for the far north end of the King County Airport/Boeing Field and parts of Georgetown. It was separated in 1976 and converted to a storm drain. At that time, the drain collected runoff from the north end of the airport and also functioned as an emergency overflow for City sewer pump station (#44), located on Airport Way S. As described above, the pump station was replumbed to the 60-inch King County Airport SD #3/PS44 EOF in about 1985.

- **Georgetown Flume.** The Georgetown flume, constructed in the early 1900s, originally discharged cooling water from the Georgetown Steam Plant to the Duwamish Waterway. Except for annual test runs, routine cooling water discharges were discontinued in the 1960s when the steam plant was shut down (SEA 2004).⁴ At one time, discharges to the flume included runoff from an estimated 11.5 acres of the north end of the airport (North Boeing Field) and industrial wastewater discharges. Numerous unpermitted storm drains and pipes from adjacent properties also connected to the flume. All known, unpermitted connections were plugged in the mid-1980s; most were replumbed to the King County Airport drainage system (60-inch King County Airport SD #3/PS44 EOF). The flume now receives stormwater runoff from an estimated 10 acres. During a 2005 field inspection, six unplugged pipes were observed entering the flume (see Appendix B).
- **I-5 SD.** This 72-inch outfall collects runoff from approximately 1.5 miles of I-5 (75 acres), 44 acres of single-family residential property located east of I-5, and 1 to 2 acres on the north end of the King County Airport.
- **East Marginal Way PS EOF.** The King County East Marginal Way pump station (PS) is connected to the East Marginal Way PS EOF. This PS has not overflowed to Slip 4 in the last 20 years. In January 2005, Emerald Services reported that flow from a manhole downstream of this pump station was entering their property and discharging to Slip 4 (Smith 2005, pers. comm.). An investigation determined that the interceptor, downstream of the East Marginal Way pump station, was at capacity so the surcharge was backing up and coming out of a manhole at the force main discharge structure. It appeared that most of the surcharge was contained within the parking area at the pump station (Zimmer 2005, pers. comm.). King County is investigating the situation to determine if operational changes resulted in this release and the potential for repeated releases by this pathway (Stern 2006, pers. comm.).

⁴ The last annual test run was in 1974; it lasted only three hours (Geissinger 2005, pers. comm.).

- **Private outfalls.** Several private outfalls discharge directly to Slip 4. Most of these outfalls appear to be private storm drains serving the mostly industrial and commercial areas immediately adjacent to the slip (approximately 50 acres).

2.6.1.2 Bank Erosion

Over two-thirds of the Slip 4 bank is armored with riprap or bulkheads, and erosion and soil transport from these protected banks is minimal. However, the east shoreline and head of Slip 4, as well as the area north of the Crowley pier, include exposed bank. Within the removal area, the shoreline has been divided into five zones based on physical and chemical characteristics (Figure 2-18). These zones are briefly described below. PCB concentrations in bank soil samples are shown on Figures 2-10 and 2-17.

Zone 1: This zone is located beneath the Crowley pier and is mostly steeply sloped riprap next to a vertical bulkhead. Because the bank is armored with riprap, there is little erosion potential, and sediment chemistry data were not collected in this area. There are some sediment deposits overlying the riprap in the outer 20–25 feet of the under-pier area. These sediments could present a recontamination potential if not addressed by the removal action.

Zone 2: This zone extends from the north edge of the Crowley pier, around the head of the slip to the 60-inch King County Airport SD #3/PS44 EOF outfall. Although vegetated, much of the bank is steeply sloped, and there is some erosion potential. A minor amount of erosion was observed during a 2004 site visit. However, a soil sample collected in this area (BK-01) contained only 2.4 mg/kg OC (23 µg/kg DW) PCBs. This result suggests Zone 2 bank soils do not present a potential recontamination source.

Zone 3: This zone extends from the 60-inch King County Airport SD #3/PS44 EOF outfall to the edge of the existing bulkhead on First South Properties. There is active erosion of exposed bank soils in this area and a failed bulkhead. PCB concentrations in the upper bank soils (BK-02 and BK03) exceed the SQS, ranging from 47 to 48.6 mg/kg OC (850 to 4,700 µg/kg DW). In samples collected for Ecology in 2005 (Parametrix 2005), PCB concentrations in surface and shallow subsurface bank sediment ranged from 7.8 to 829 mg/kg OC. PCB concentrations in nearshore upland soil borings ranged from nondetected to 51 mg/kg OC. One surface sample collected by CH2M Hill in an upland drainage swale contained 810 mg/kg OC PCBs (CH2M Hill 2005a,b). If not addressed, the Zone 3 bank is considered to pose significant recontamination potential to Slip 4 sediments.

Zone 4: This zone is comprised of the bulkhead on the east bank (along the southern half of First South properties). This wooden bulkhead is estimated from aerial photos to be approximately 50 years old. Indications of relatively recent fill placement observed along this bulkhead during a recent site visit suggest erosion has occurred in the past. PCB concentrations in two soil samples from gaps in the bulkhead (BK-04 and BK-05) were

20.2 and 26.3 mg/kg OC (790 and 1,300 µg/kg DW) and exceed the SQS. In the northern 100 feet of Zone 4, Ecology's 2005 investigation revealed that fill material behind this portion of the bulkhead contains PCBs at concentrations up to 127 mg/kg OC, exceeding the CSL. Soils behind the northern 100 feet of the Zone 4 bulkhead may pose a recontamination potential to Slip 4 sediments. In the southern 180 feet of Zone 4, PCBs were not detected in soil samples from three nearshore soil borings. Although the bulkhead is deteriorated, it generally contains the fill material and only limited soil erosion is occurring (primarily from near the top of the bank). Based on these investigations, the recontamination potential for the northern 100 feet of Zone 4 bank is considered potentially significant. The recontamination potential for the southern 180 feet of Zone 4 bank is considered small.

Zone 5: This zone is located between the bulkhead and the northeast limits of engineered riprap along the Boeing property shoreline. The bank in this area is actively eroding fill material. The 2004 bank sample BK-06 contained 402 mg/kg OC (7,800 µg/kg DW) PCBs, substantially exceeding the SQS and CSL. In samples collected for Ecology in 2005 (Parametrix 2005), PCB concentrations in surface and shallow subsurface bank sediment ranged from 5.8 to 68 mg/kg OC PCBs. PCB concentrations in nearshore upland soil borings ranged from nondetected to 14 mg/kg OC. Additional samples collected in the vicinity of BK-06 in 2005 had 5.4 to 16.7 mg/kg OC PCBs (Bach 2005b, pers. comm.), indicating considerable heterogeneity in the soil. If not addressed, the Zone 5 bank is considered to pose significant recontamination potential to Slip 4 sediments.

2.6.2 Summary of Source Control Activities

Ecology is the designated lead for source control activities in the LDW and works with other members of the LDW Source Control Work Group (City of Seattle, King County, the Port of Seattle, the City of Tukwila, and EPA) to investigate and control sources discharging to the waterway. The source control strategy for the LDW is to minimize the potential for chemicals in sediments to exceed the sediment management standards and LDW cleanup goals by identifying and managing pollutant sources. The strategy places the highest priority on controlling sources in the early action areas, including Slip 4, since these areas will be cleaned up first. Ecology has prepared a draft of the *Lower Duwamish Waterway Source Control Action Plan for the Slip 4 Early Action Area* (Ecology 2006).

2.6.2.1 City of Seattle and King County

The City of Seattle owns and operates the municipal separated storm drain system that collects stormwater runoff from upland areas and discharges to Slip 4 and the small sanitary/combined sewer system that collects municipal and industrial wastewater within the City service area. King County owns and operates the larger interceptor system that conveys wastewater to the treatment plant at West Point. The City and King County each

own and operate sewer pump stations that in an emergency would discharge overflow to Slip 4.

City and County source control activities focus on reducing the amount of chemicals discharged to publicly owned storm drains and sanitary/combined sewers through business inspections and source identification/tracing work. Because there are no combined sewer overflows (CSOs) into Slip 4 and pump station emergency overflows occur infrequently, source control activities have focused on stormwater discharges. The City and County provide progress reports to the agencies every 6 months. Detailed information is available in the June 2004, January 2005, and June 2005 reports (King County and SPU 2004, 2005a,b).

Source control work completed to date by the City and King County includes inspections of businesses in the Slip 4 drainage basin; source tracing and identification using storm drain sediment traps and collection of inline and catch basin sediment samples; and an investigation of the Georgetown flume. The results of these investigations are summarized in Table 2-10 and detailed in Appendix B. In summary, the results indicate potentially significant ongoing sources of PCBs and phthalates to Slip 4 from upland drainage systems.

2.6.2.2 Washington Department of Ecology

As the lead agency for LDW source control, Ecology may use its regulatory authority to oversee or implement controls for properties that discharge directly to the waterway and contaminated properties that may impact sediments. Ecology also assists local agencies on source control issues and activities (Ecology 2004). A public review draft of the *Lower Duwamish Waterway Source Control Action Plan for the Slip 4 Early Action Area* (Ecology 2006) will be available in February 2006.

Ecology also conducts site inspections. On December 16, 2005, Ecology staff inspected North King County Airport Boeing-leased facilities. Ecology has requested additional information from Boeing before preparing an inspection report. Results of the inspection are discussed in the *Lower Duwamish Waterway Source Control Action Plan for the Slip 4 Early Action Area* (Ecology 2006).

2.6.2.3 Boeing Source Investigations

The Boeing Company has been investigating potential sources of PCBs in the area around North Boeing Field (Bach 2005c, pers. comm.). Sediment samples collected from catch basins between 1992 and 2005 contained elevated concentrations of PCBs (0.87–1,310 mg/kg DW). With the exception of station CB173 (247–1,310 mg/kg DW), the highest concentrations (17–342 mg/kg DW) were generally found in the samples collected prior to 2001. Boeing reports that catch basins on North Boeing Field are cleaned every

year. However, samples collected in 2005 continue to exhibit elevated concentrations of PCBs (19 of 29 samples contained 10–50 mg/kg DW, not including CB173).

Boeing has identified concrete joint material (caulk) present in the pavement on North Boeing Field as one potential source of PCBs in the catch basin sediments (Landau 2001). Samples of caulk material contain <1 to 79,000 mg/kg DW PCBs. The highest concentrations of PCBs are generally found in three types of caulk (Type A, G, and H).

Since 2002, Boeing has been working to remove PCB-contaminated joint material from the paved areas on North Boeing Field. As of 2005, approximately 57,000 linear feet of caulk material has been removed (Cargill 2006, pers. comm.). An estimated 1,500 linear feet of caulk is scheduled to be removed in 2006

In addition, Boeing is currently conducting source tracing activities in the storm drains serving North Boeing Field to identify other possible sources of PCBs to the drainage system (Bach 2005b, pers. comm.). Work involves sampling catch basins upstream of the SPU sediment trap site found to contain elevated concentrations of PCBs (SL4-T5) and collecting filter samples during storm events to identify possible sources.

2.6.2.4 Interpretation of Existing Source Control Data

The results of investigations by the City, King County, and Boeing indicate potentially significant ongoing sources of PCBs to Slip 4 from upland areas. Sediment samples collected from the following storm drains in Slip 4 exhibit elevated concentrations of PCBs:

- 60-inch King County Airport SD #3/PS44 EOF (inline sediment samples, sediment traps, and catch basin sediment samples)
- 72-inch I-5 SD (one sediment trap sample)
- Georgetown flume (multiple inline sediment samples).

Ecology, King County, Seattle City Light, SPU, and The Boeing Company are continuing to investigate and implement controls to address these sources.

In addition, there may be a potential ongoing source of BEHP at the First South Properties/Emerald Services property. BEHP is elevated above the CSL of 78 mg/kg OC in catch basin sediments (34–1,869 mg/kg OC) and soil from a drainage area (177 mg/kg OC) on this property. Because the concentration of BEHP was also above the CSL in subtidal sediments at a Slip 4 location adjacent to First South Properties (Station SG06), additional evaluation of phthalates at this property may be warranted.

It is important that these sources are adequately controlled prior to construction of the Slip 4 removal action to minimize the potential for recontamination of Slip 4 sediments.

The criteria for evaluating the effectiveness of the ongoing source control efforts are discussed in the following subsection.

2.6.3 Criteria for Evaluating Effectiveness of Source Control

Ecology will make the final decision regarding source control effectiveness and completeness (Ecology 2004). Specific criteria are included in Ecology's *Lower Duwamish Waterway Source Control Action Plan for the Slip 4 Early Action Area* (Ecology 2006). The general approach is described by Ecology (2004) and briefly summarized here. When the Source Control Action Plan (Ecology 2006) has been fully implemented, Ecology will assess the effectiveness of the source control actions. Ecology may require some form of monitoring, such as direct measurement of chemicals in sediments or sources (e.g., storm drains, catch basins), or evaluation of data from other investigations. Ecology will determine that source control is complete when actions have been implemented that prevent or minimize the potential for recontamination of sediments. Ecology's final decisions on source control effectiveness and completeness will be documented in a *Source Control Effectiveness and Completeness Determination* and will require EPA review and concurrence.

Following EPA and Ecology's assessment and before implementing cleanup actions, the City of Seattle and King County will consider whether or not source control is considered adequate to prevent significant recontamination.

2.6.4 Integrating Source Control Elements into the Removal Action

Potentially significant upland sources of recontamination identified for Slip 4 are continued erosion of bank material and contaminant loading from storm drains.

2.6.4.1 Erosion of Bank Material

The City has been coordinating closely with Ecology regarding investigation of the Slip 4 banks. Ecology determined that upland soil at First South Properties is not a major ongoing source of recontamination to Slip 4 (Ecology 2005). No Ecology-led upland cleanup actions are currently planned. However, active erosion of bank material in Zone 3, Zone 5, and a portion of Zone 4 is a potential source of PCB contamination. Because bank material is a potential source of recontamination to Slip 4 sediments, this EE/CA includes actions to stabilize and contain the banks as part of the NTCRA. The City will continue to coordinate with Ecology throughout the design process.

2.6.4.2 Storm Drains

Recent storm drain investigations by King County, SPU and Boeing indicate that sediment found in storm drains discharging to Slip 4 remain a potential source of recontamination, particularly for PCBs. Source control actions are currently being implemented (e.g., drain cleaning, source tracing) and will continue, along with further

investigation and monitoring, concurrent with the NTCRA process. The effectiveness and completeness of storm drain source control will be included in Ecology's *Source Control Effectiveness and Completeness Determination*. Sediment cleanup will not be implemented until the City of Seattle, King County, Ecology, and EPA agree that source control appears adequate to prevent significant sediment recontamination.

In addition to these upland source control issues, sediment accumulations within the Georgetown flume near the outfall are currently being investigated by the City. (Large amounts of sediment accumulation extend from Slip 4 up into the 370-foot outfall segment of the flume. Such accumulations are not present at the other outfalls to Slip 4.) If not removed, the sediments near the Georgetown flume outfall could be transported into Slip 4 following the cleanup. The removal action design will include measures to remove or otherwise contain any substantial accumulations of sediment from the flume immediately upgradient of the outfall.

3 IDENTIFICATION OF REMOVAL ACTION SCOPE, GOALS, AND OBJECTIVES FOR SLIP 4 EAA

This section identifies the scope and role of the Slip 4 NTCRA, the specific rationale for the final boundaries of the EAA, and the goals and objectives that the removal action is intended to achieve. These elements have been developed consistent with the regulatory framework of the National Contingency Plan (40 CFR 300.415) and in consideration of applicable or relevant and appropriate requirements (ARARs).

3.1 REMOVAL ACTION SCOPE

3.1.1 Role of Slip 4 NTCRA in the LDW Cleanup

The Slip 4 site has been identified as one of seven candidate early action areas within the LDW Superfund Site. The purpose of these early actions is to significantly reduce exposure of ecological and human receptors to sediment contamination, and to prevent any future migration of source material that may be contributing to elevated concentrations of target compounds in the LDW. This NTCRA will address contaminated sediments within the Slip 4 EAA; the removal boundaries encompass approximately the northern half, or head, of Slip 4 (Figure 3-1).

Once the early actions are completed, the remaining areas of the LDW will be evaluated and remediated under EPA's Superfund program. The final remedy for the entire LDW Superfund Site, including Slip 4, will be selected after additional characterization of the nature and extent of contamination, completion of a baseline risk assessment and other RI/FS documentation, and public comment on the proposed plan. Cleanup of the remainder of the LDW will occur through additional NTCRAs and/or remedial design/remedial action (RD/RA) following remedy selection.

Following the Slip 4 NTCRA it is anticipated that no further remedial action will be needed to address sediments within the Slip 4 removal area boundary. Long-term monitoring of the cleanup in Slip 4 will be performed to ensure the protectiveness of the remedy. A final determination of the remedy for all Slip 4 sediments will be made in the ROD for the LDW. Consistent with the NCP [40 CFR 300.415(c)], the Slip 4 NTCRA is expected to contribute to the efficient and successful performance of the anticipated remedial action for the LDW Superfund Site.

3.1.2 Removal Boundaries

The *Revised Draft Technical Memorandum on Proposed Boundary of the Removal Action* (see Appendix A) defines proposed boundaries for the Slip 4 removal action and presents detailed rationale and supporting data for the removal area boundaries. The proposed removal boundaries were developed with consideration of the SMS criteria corresponding to a low likelihood of adverse effects on biological resources (the SQS for PCBs is

12 mg/kg OC). The final removal boundaries for this EE/CA have been revised to include certain shoreline/bank areas, as described below. Figure 3-1 shows a detailed topographic and bathymetric contour map of the proposed and final removal boundaries.

3.1.2.1 Subtidal Boundary

The subtidal removal boundary extends across Slip 4 and is defined by the edge of the engineered riprap slope (on the northwest edge of property owned by The Boeing Company) and the northern permitted limits of 1996 dredging in front of the Crowley pier. This boundary encompasses all areas with SQS exceedances in surface (0–10 cm) sediments, with the exception of minor SQS exceedances for PCBs, phenol, and BEHP at one sampling station (SG-16). Based on 2004 data, surface sediments in the portion of the slip outside the removal area (from the boundary out to the navigation channel line) have an average total PCB concentration of 5.6 mg/kg OC. The 95-percent upper confidence limit on the mean is 7.0 mg/kg OC). Following the removal action, surface sediments within the removal boundary will have total PCB concentrations below the SQS. The proposed subtidal removal boundary identified in the technical memorandum has not been modified in this EE/CA.

3.1.2.2 Nearshore Boundary

The technical memorandum identifies five shoreline zones, reflecting physical shoreline features and bank soil chemistry information. These zones are depicted in Figure 3-1. The zones, along with the proposed and final removal boundaries, are described below:

- **Zone 1** extends approximately 450 linear feet along the Crowley pier. The proposed removal action boundary (Appendix A) was originally located at the pier face. Information from a 2004 survey and from original pier construction diagrams indicates that significant accumulations of sediment exist atop the riprap beneath the pier. These under-pier sediments may have chemical concentrations similar to those measured at nearby coring locations (e.g., SC-02 and SC-03). If not specifically addressed in design, these sediments could pose significant recontamination potential. Therefore, the final removal boundary in this EE/CA extends under the pier approximately 20–25 feet to the point where the sediment deposits meet the riprap. The removal alternatives address these under-pier sediments through removal and/or containment actions. Additional information regarding the extent and chemical concentrations within under-pier sediments may be generated during the design phase.
- **Zone 2** extends approximately 290 linear feet from the northern edge of the Crowley pier, around the head of the slip to the 60-inch King County Airport SD #3/PS44 EOF outfall. The proposed removal action boundary is at the toe of the bank in this area and ranges in elevation from approximately +5 to +8 feet MLLW. Bank sample BK-01 (collected at approximately +10 feet MLLW) was collected

west of the outfalls in this area and contained only 2.4 mg/kg OC PCBs. The proposed Zone 2 removal boundary identified in the technical memorandum has not been modified in this EE/CA. However, predesign investigations will include additional sampling of the Zone 2 bank. Should this investigation find elevated chemical concentrations, the design for this removal action may include elements to remove or contain any actively eroding bank soils with elevated chemical concentrations. Under some cleanup alternatives, portions of the Zone 2 bank may be excavated as a design element for habitat enhancement purposes. In addition, sediment accumulations within the Georgetown flume (within the 370-foot pipe segment near the outfall) are currently being investigated by the City. If not addressed, these sediments could be transported into Slip 4 following the cleanup. The alternatives include measures to remove or otherwise contain any substantial accumulations of sediment from this segment of the pipe immediately upgradient of the outfall.

- **Zone 3** extends approximately 300 linear feet from the 60-inch King County Airport SD #3/PS44 EOF outfall to the edge of the existing bulkhead on First South Properties. The proposed removal action boundary was originally at the toe of the bank in this region, which ranges in elevation from about +6 to +10 feet MLLW. A failed bulkhead is present in a portion of this area. Bank samples BK02 and BK03 (collected at approximately +10 feet MLLW) contained 47 and 48.6 mg/kg OC PCBs, respectively. In samples collected for Ecology in 2005 (Parametrix 2005), PCB concentrations in surface and shallow subsurface bank sediment ranged from 7.8 to 829 mg/kg OC. PCB concentrations in nearshore upland soil borings ranged from nondetected to 51 mg/kg OC. One surface sample collected by CH2M Hill (2005) in an upland drainage swale contained 810 mg/kg OC PCBs. The bank is composed of fill material. Because this fill material is a potential source of recontamination to Slip 4 sediments, the final removal boundary in this EE/CA has been extended to the top of the bank in Zone 3 and includes the drainage swale. The removal alternatives include actions to stabilize the bank and remove and/or contain impacted bank soils. Under some cleanup alternatives, portions of the Zone 3 bank may also be excavated as a design element for habitat enhancement purposes.
- **Zone 4** extends approximately 280 linear feet along the bulkhead on the southern half of First South Properties. The proposed removal action boundary was originally set at the toe of the bulkhead at approximately +5 feet MLLW. In the northern 100 feet of Zone 4, Ecology's 2005 investigation revealed that fill material behind this portion of the bulkhead contained PCBs at concentrations up to 127 mg/kg OC. Because this fill material is a potential source of recontamination to Slip 4 sediments, the final removal boundary in this EE/CA has been extended to the top of the bank in the northern 100 feet of Zone 4. The removal alternatives include actions to stabilize the bank and remove and/or contain impacted bank

soils. In the southern 180 feet of Zone 4, PCBs were not detected in soil samples from three nearshore soil borings. Bank sample BK05 (26.3 mg/kg OC PCBs) also represents fill material located behind the bulkhead in this area. Because the fill material exhibits only one minor SQS exceedance, and the bulkhead is currently containing the fill, the fill is not considered to pose a significant recontamination potential for Slip 4 sediments. The final removal boundary remains at the toe of the bulkhead in the southern 180 feet of Zone 4. The long-term integrity of the bulkhead in the southern 180 feet of Zone 4 will remain the responsibility of the landowner(s).

- **Zone 5** extends approximately 140 linear feet between the Zone 4 bulkhead and the northeast limits of engineered riprap that is present along the Boeing shoreline. A chain-link fence at the top of the bank coincides with the limits of the riprap. The proposed removal action boundary was originally located at the toe of the bank in Area 5, which is located at about +5 feet MLLW. The bank in this area comprises actively eroding fill material. Bank sample BK06 (collected at approximately +10 feet MLLW in this area) contained 402 mg/kg OC PCBs. In samples collected for Ecology in 2005 (Parametrix 2005), PCB concentrations in surface and shallow subsurface bank sediment ranged from 5.8 to 68 mg/kg OC PCBs. PCB concentrations in nearshore upland soil borings ranged from nondetected to 14 mg/kg OC. Because this fill material is a potential source of recontamination to Slip 4 sediments, the final removal boundary in this EE/CA has been extended to the top of the bank in Zone 5. The removal alternatives include actions to stabilize the bank and remove and/or contain impacted bank soils.

The final removal area (Figure 3-1) encompasses a total area of 3.6 acres.

3.1.3 Other Factors Critical to the Removal Action Scope

The following is a summary of additional project elements and site characteristics that have been considered in the development of the removal action scope:

- The removal boundary presented in Figure 3-1 establishes the outer limit of the Slip 4 removal action. During design, some adjustments may be made to the boundary based on predesign sampling results.
- The primary chemicals of concern identified for the Slip 4 removal action are PCBs, which are found in bank soils and intertidal and subtidal aquatic sediments. Actions to address PCBs will also address the other contaminants found in site soils and sediments.
- Asphalt, creosote-treated timbers and piles, and other debris are present in intertidal sediments at the head of Slip 4 and along the shoreline. The scope includes removal of this material, as necessary, for implementation of the removal action.

- As discussed in Section 2.6.4, source control actions for stormwater by Ecology, the City of Seattle, and King County are ongoing and will continue during planning and implementation of the Slip 4 sediment removal action. Most source control activities will occur prior to implementation of the removal action (e.g., drain sampling) or will be ongoing (e.g., best management practices). The source control actions are outside the scope of this EE/CA. EPA and Ecology will coordinate to ensure that source control actions are sufficiently complete prior to cleanup.
- Significant sediment accumulations extend from Slip 4 up into the outfall segment of the Georgetown flume. The alternatives include measures to remove or otherwise contain any substantial accumulations of sediment from this segment of the pipe immediately upgradient of the outfall.
- The other remaining significant upland source of potential recontamination identified for Slip 4 is the active erosion of bank material in Zones 3, 4, and 5 containing PCBs significantly above the SQS. If left unaddressed, these banks have the potential to erode into Slip 4 and recontaminate sediments.
- Site studies (described in Section 2.3.3) have shown that the groundwater (and groundwater that is expressed as surface water seeps into Slip 4) does not contain detectable concentrations of PCBs. Groundwater from upland areas is not considered a significant pathway for release of PCBs or other contaminants to Slip 4.
- Along the Zone 3, 4, and 5 banks, the scope of the removal action includes actions to stabilize the bank and remove and/or contain impacted bank soils. Removal (excavation) of bank soils is included in the actions' scope as needed to stabilize the bank, prepare the bank for capping, and avoid loss of aquatic habitat. The bank removal scope does not include continued excavation into upland areas to attempt complete removal of all impacted upland fill material. Post-excavation sampling will document soil conditions underneath the bank caps. Ecology (2005) has completed its characterization of these embankment areas and determined that there is no significant upland contamination and no need for any additional source control actions to address any remaining contaminants in upland fill material. The City will continue to coordinate with Ecology throughout the design process.
- Along the Zone 2 bank, a predesign investigation will be conducted. If elevated chemical concentrations are found, the design for this removal action may include elements to remove or contain any actively eroding bank soils with elevated chemical concentrations.
- The historical and recent sediment sampling data show a spatial trend of PCB concentrations that generally decrease from the mudflat area at the head of Slip 4 out toward the subtidal removal boundary. The highest observed concentrations

of PCBs within the removal area are found in the mudflat at the head of Slip 4 within the upper 0–2 feet of sediments.

- Within the removal area, the layer of PCB-containing sediment ranges from 4 feet thick to greater than 9 feet thick. Slope and structural stability considerations limit the ability to excavate or dredge all sediments exceeding the SQS, particularly in areas adjacent to the Zone 2 bank and the Zone 4 bulkhead. Slope and structural stability considerations are discussed further in the development of alternatives (Section 5).
- Six species reported in the LDW are listed under the federal ESA as candidate species, threatened species, or species of concern (Table 2-2). Of these, chinook salmon, coho salmon, bull trout, peregrine falcon, and bald eagle may use the LDW on more than an incidental basis. The Slip 4 early action will be implemented according to the constraints set forth by the ESA process, with a goal of no net loss of aquatic habitat acreage. Similarly, federal Clean Water Act (CWA) 404 requirements are considered in the alternative development as they relate to the effects of dredging and filling on habitat.
- Slip 4 is within the usual and accustomed fishing areas of the Muckleshoot Tribe. Within the Slip 4 EAA, salmon may be harvested by the Muckleshoots, and viable shellfish habitat is present. Removal alternatives should not interfere with treaty rights to these resources.
- Within the Slip 4 EAA, Crowley's inner berth has a USACE-permitted depth of -15 feet MLLW (USACE 1981). Since 1981, considerable shoaling has reduced depths in this area, resulting in increased intertidal and shallow subtidal acreage relative to the historically permitted conditions. Effects of removal alternatives on habitat acreages are evaluated relative to both existing conditions and the historically permitted conditions. Significant deepening or lateral expansion of the historically permitted dredge prism could result in the need for mitigation under CWA 404, and is outside the scope of this removal action.

3.2 REMOVAL ACTION GOALS AND OBJECTIVES

The goal of the NTCRA at Slip 4 is to conduct an early cleanup that significantly reduces exposure of ecological and human receptors to sediment contamination, thereby reducing or eliminating adverse effects on biological resources in the removal area. As described in Section 2.4, surface sediments within much of the proposed removal boundary area exceed SMS chemical criteria, indicating that these sediments may pose a risk to benthic community health if no cleanup action is taken. Also, the Phase 1 HHRA identified potential risks to human receptors associated with PCBs in the LDW. This NTCRA will reduce potential risks to human health by removing or isolating bioaccumulative chemicals that are found in sediment. Human health risks for the entire LDW will

ultimately be addressed in the ROD, which will establish human-health-based cleanup levels.

Based on the streamlined ecological and human health risk evaluations (as summarized in Section 2.4), the following removal action objective (RAO) was developed for the Slip 4 removal area as a means of meeting the stated goal:

- Reduce the concentrations of contaminants in post-cleanup surface sediments [biologically active zone (0–10 cm)] to below the state Sediment Quality Standards (SQS) for PCBs and other chemicals of interest.

Contaminated source material in bank areas adjacent to the removal boundary and in the outfall segment of the Georgetown flume will be addressed such that contaminants will not be released into the waterway or result in unacceptable exposure to human and ecological receptors.

For this removal action, the post-construction surface sediment concentrations will be at or below the SQS chemical criteria of the SMS (WAC 173-204-320) for all chemicals of interest. Sediments that meet the SQS chemical criteria are expected to have no adverse effects on biological resources. These concentration goals have been developed on a site-specific basis for Slip 4, consistent with the requirements of the SMS (WAC 173-204-570). Attaining these concentrations in surface sediments (0–10 cm) represents compliance with the RAO. Also, the removal action will result in a new sediment surface throughout Slip 4 that will have lower chemical concentrations than the existing surface, and therefore will comply with SMS anti-degradation requirements of WAC 173-204-120. The final cleanup standards for the LDW site will be developed in the ROD, taking into account human health risk from bioaccumulative compounds. Once the ROD for the LDW site is finalized, then the protectiveness (to both ecological and human receptors) of the completed removal action will be evaluated based on cleanup levels identified in the ROD.

The National Contingency Plan (NCP) [40 CFR 300.415(c)] states that removal actions shall, to the extent practicable, contribute to the efficient performance of any anticipated long-term remedial action with respect to the release concerned. Therefore, the removal action will:

- Contribute to the efficient performance of any long-term remedial action on the LDW
- Be protective of human health and the environment in the long-term.

As discussed in Section 4, the RAO can be attained through removal and/or containment actions. Post-construction monitoring will verify that chemical concentrations in the post-construction surface sediments are less than the SQS. Corrective actions (e.g., additional

dredging or capping) will be implemented, as needed, to ensure that the removal area meets these chemical criteria.

3.3 REMOVAL ACTION SCHEDULE

The Slip 4 NTCRA is scheduled to occur during the summer 2007 / winter 2008 construction season. Consistent with Washington State Hydraulic Code rules and ESA requirements, dredging and other in-water work cannot occur during identified “fish window” closure periods. The specific dates of these closures will be identified in consultation with NOAA Fisheries and the U.S. Fish and Wildlife Service (USFWS). It is currently anticipated that in-water dredging or capping of contaminated material will be permitted only between October 1, 2007 and February 15, 2008. It is possible that some construction elements could be completed “in-the-dry” earlier than October 1, 2007 if approved by EPA in coordination with NOAA Fisheries and USFWS.

As discussed in Section 2.6.4, source control actions for stormwater by Ecology, the City of Seattle, and King County are ongoing. The source control actions are outside the scope of this EE/CA; however, the construction schedule for the Slip 4 removal action may be affected by the status of the ongoing stormwater source control efforts. The City of Seattle and King County will coordinate closely with EPA in their assessment of any potential schedule impacts.

Once an alternative is selected by EPA, the City and King County will conduct a predesign investigation to fill any remaining data gaps that are relevant to the selected alternative. This investigation is expected to occur in 2006.

In addition to these general schedule requirements, the removal action will be coordinated with tribal netfishing in the LDW, which may affect the construction schedule.

3.4 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

All removal actions conducted under CERCLA authority must comply with other state and federal ARARs to the extent practicable given the urgency of the situation and the scope of the removal action [40 CFR 300.415(i)]. ARARs pertinent to site remediation have been identified and considered in defining the scope and the RAO of this NTCRA as well as in the selection of the preferred alternative.

ARARs and to-be-considered requirements for the Slip 4 NTCRA are summarized in Section 6 of this EE/CA. The alternatives presented in Sections 5 and 6 have been evaluated for compliance with these ARARs. The design for the selected alternative will provide further specifics regarding compliance with ARARs. During the removal action,

the substantive requirements of these ARARs will be met to the extent practicable, as required by the NCP.

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4 IDENTIFICATION OF REMOVAL ACTION TECHNOLOGIES

This section identifies removal action technologies and evaluates these technologies for their applicability to the Slip 4 NTCRA. The identification and evaluation of technologies for Slip 4 takes into account the broader range of technologies identified by the LDWG in the Candidate Technologies Memorandum (CTM) (RETEC 2005) and other studies such as multiuser disposal sites (MUDS) (USACE 2003). These sources identify several cleanup technologies that are considered potentially applicable to sediment remediation, with particular emphasis on their applicability to remedial actions for the LDW as a whole. The evaluation in this EE/CA focuses on demonstrated technologies appropriate for the size, time frame, and site-specific conditions of the Slip 4 NTCRA. Generally, technologies that were screened and eliminated in the CTM for application in the LDW are not discussed in this screening.

Removal action technologies considered for the Slip 4 EAA fall into the following general response action (GRA) categories:

- No Action
- Institutional Controls
- Monitored Natural Recovery and Enhanced Natural Recovery
- Removal
- Containment
- Treatment
- Disposal.

Technologies within each GRA that are considered applicable for Slip 4 are briefly discussed and evaluated in the following subsections. Consistent with EPA guidance (USEPA 1993), the technologies are evaluated based on effectiveness, implementability, and cost. These criteria are discussed in greater detail in Section 5.

No Action is not considered an applicable GRA for Slip 4. As discussed in Section 2.4.2, PCB concentrations in surface sediments within the Slip 4 EAA indicate adverse effects on biological resources and contribute to potential human health risks throughout the LDW. No action would not address these risks or satisfy the RAO for the removal action. Therefore, a no-action alternative is not developed in this EE/CA.

Refer to the CTM (RETEC 2005) for further discussion of technology specifics as they apply to conditions within the LDW as a whole.

4.1 INSTITUTIONAL CONTROLS

4.1.1 Description and Applicability

The term “institutional controls” refers to nonengineering measures intended to ensure the protectiveness of the remedy and to affect human activities and ecological receptors in such a way as to prevent or reduce the potential for exposure to contaminated media (USEPA 2000). These controls may include elements such as fish consumption advisories, land use restrictions including easements or covenants, waterway use restrictions, or similar measures. Much of the information in this section is summarized from EPA guidance (USEPA 2000, 2003, 2004, and 2005c).

Institutional controls can play an important role when a cleanup is conducted and when it is too difficult or too costly to remove all contamination from a site (USEPA 2000). Institutional controls are rarely used alone to deal with contamination at a site. Typically, institutional controls are part of a larger cleanup solution and serve as a nonengineered layer of protection. Institutional controls are designed to keep people from using the site in a way that is not safe, thus, potentially jeopardizing protection of people and the environment. Institutional controls are normally used when some amount of contamination remains on-site as part of a cleanup remedy and when there is a limit to the activities that can safely take place at the site (i.e., the site cannot support unlimited use and unrestricted exposure). Institutional controls are also used to preserve the long-term protectiveness of the remedy.

According to EPA (2005c), institutional controls are generally divided into four categories: 1) **Government Controls**—include local laws or permits (e.g., county zoning, building permits, and Base Master Plans at military facilities); 2) **Proprietary Controls**—include property use restrictions based on private property law (e.g., easements and covenants); 3) **Enforcement Tools**—include documents that require individuals or companies to conduct or prohibit specific actions (e.g., environmental cleanup consent decrees, unilateral orders, or permits); and, 4) **Informational Devices**—include deed notices or public advisories that alert and educate people about a site. The use of institutional controls at EPA cleanup sites is further described in EPA guidance (USEPA 2005c, 2004, 2000, 1999b).

Institutional controls, by themselves, would not be protective of the environment or satisfy the RAO for the Slip 4 EAA. Institutional controls are potentially applicable and are retained as potential components of alternatives that also include active cleanup. For example, on privately owned lands, restrictive covenants (a form of Proprietary Controls) can be effective in maintaining the long-term integrity of capping or other containment actions. For the purposes of this EE/CA, such Proprietary Controls are referred to as “land use restrictions.”

4.1.2 Evaluation

Institutional controls are effective, implementable, and cost-effective, and are retained as a potential component of active remediation alternatives.

4.2 MONITORED NATURAL RECOVERY AND ENHANCED NATURAL RECOVERY

4.2.1 Description and Applicability

Monitored natural recovery (MNR) is a risk management approach that relies upon natural environmental processes to permanently reduce exposure and risks associated with contaminated sediments. Enhanced natural recovery (ENR) involves the placement of a thin layer of clean sand or sediment over areas with relatively low contaminant concentrations to speed up or enhance the natural recovery processes already demonstrated to be occurring at a site. ENR is also sometimes used in conjunction with an active removal remedy as a means of managing residual contamination that sometimes remains after a cleanup.

These technologies are potentially applicable in combination with other response actions, and, in particular, may be applicable in addressing thin deposits of residual contaminated sediments that may remain following dredging (i.e., dredge residuals).

4.2.2 Evaluation

By themselves, MNR and ENR would not be effective in achieving the RAO. MNR and ENR are retained as potential contingency actions that may be implemented as a means of dealing with dredge residuals in active remediation alternatives. They are potentially effective, implementable, and cost-effective.

4.3 REMOVAL

4.3.1 Description and Applicability

As a general response action, removal refers to technologies for the physical excavation of material from the waterway. The excavated material would then need to be handled through treatment and/or disposal technologies. As it applies to Slip 4, removal technologies could be used to satisfy a range of potential design objectives:

- **Ensuring no net loss of aquatic habitat.** This objective applies to embankment areas, where capping without prior removal would create a loss of aquatic habitat.
- **Accommodating outfall drainage.** This objective applies to the mudflat area at the head of Slip 4, where capping without prior removal would obstruct the flow of water from outfalls.

- **Removing contaminated material in navigation areas / Re-establishing historically permitted navigation depths.** This objective could apply to the inner berth area, which historically has been permitted to a depth of -15 feet MLLW. Minimal navigation currently occurs in this area, and this objective does not apply to all alternatives considered. The observed extent of SQS exceedances in the inner berth area generally extends to -15 feet MLLW or deeper, thus removal of this material would re-establish the permitted navigation depths.
- **Removing material with the highest concentrations of contaminants.** This objective could apply to the mudflat area at the head of Slip 4, where total PCB concentrations in near-surface sediments are comparatively high and in one sample exceeded the Toxic Substances Control Act (TSCA) regulatory threshold of 50 mg/kg DW. While sediments in this area could successfully be capped without removal, the area is subject to erosive forces, and without removal the consequences of localized cap failure could be significant.
- **Minimizing changes to mudflat habitat at the head of the slip.** This objective could apply to the mudflat area at the head of Slip 4, where capping without prior removal would convert lower intertidal habitat to upper intertidal habitat.
- **Removing all contaminated material and leaving a clean surface.** As discussed in Section 5, this objective was considered for applicability throughout the Slip 4 EAA. However, site limitations (including slope stability, structural stability of piers, outfalls, and bulkheads, and depth of contamination) limit the feasibility of complete removal of all contaminated material throughout Slip 4. Complete removal would also require extensive backfilling to minimize habitat loss. Complete removal is considered a potentially viable objective within the permitted dredge prism of the inner berth area, and complete removal would also re-establish the historically permitted navigation depths in the area.

As discussed in Section 5, alternatives may incorporate varying degrees of removal combined with other general response actions. Alternatives that satisfy the RAO and are protective of human health and the environment may not necessarily incorporate all of the removal objectives described above.

Removal technologies for the Slip 4 EAA can be implemented using two general construction technologies:

- Construction “in-the-dry,” typically using land-based construction equipment from the upland side of the site (referred to as “excavation” for the purposes of this EE/CA), or
- In-water construction, typically using floating equipment (referred to as “dredging” for the purposes of this EE/CA).

Generally, excavation will be used as practicable, given the availability of low tides during the construction time frame. Excavation will generally be used on embankments and potentially at the head of Slip 4 at elevations above approximately 0 feet MLLW. Dredging will be used throughout the remainder of the Slip 4 EAA. These two construction technologies are discussed in the following subsections.

4.3.1.1 Excavation

Excavation would be accomplished with typical earthmoving equipment and would generally occur in-the-dry when the tides are out. Excavation would generally be used on embankments and potentially at the head of Slip 4 at elevations above approximately 0 feet MLLW. (The ability to excavate at the head of the slip depends on the bottom elevation of the cut, which varies among the alternatives discussed in Section 5.) Completing excavations from the land (and in-the-dry or with minimal inundation) provides several advantages as compared to working in the water when the tides are in and the land is submerged. These advantages include:

- Operators can see the work area and accurately place the bucket to ensure complete removal to the design limits.
- Operators and oversight staff can see the excavated face and adjust the depth of excavation based on observed conditions.
- Material is maintained and removed in a relatively intact state, reducing the potential for creating a liquefied mix of sediment and water that can be difficult to capture in the excavator bucket.
- The potential for offsite transport in the water column is minimized, as minimal impacted material enters the water column.
- Some construction may be completed in-the-dry during periods when in-water work is prohibited.

In some cases, the ability to work completely in-the-dry would be limited by the practical ability to time the available low tides within the construction window. The design may identify certain areas where excavation in-the-dry is required. In other areas, working in-the-dry would not be an absolute requirement but would be identified as a preferred method to be implemented as practicable. The contractor would propose detailed work schedules and methods in its work plan, which would require approval by the City/County and EPA.

Allowable in-water construction windows will be determined by EPA in consultation with NOAA Fisheries, USFWS, WDFW, and Muckleshoot Tribe. EPA may allow work below ordinary high water outside the established in-water construction window if the work is effectively completed in-the-dry when tides are out.

Excavation would be completed with typical earthmoving equipment (excavators, front-end loaders, and dump trucks). Specially equipped long-reach excavators and low-ground pressure equipment may be appropriate to access lower areas within the head of the slip. Excavated material would be placed in properly lined trucks and transported over city streets to selected disposal or intermodal transfer facilities. Alternatively, excavated material could be loaded onto haul barges, as described for dredging in the following subsection.

4.3.1.2 Dredging

For mechanical dredging, a barge-mounted excavator or derrick would use a bucket to remove material from the bed and place it into a haul barge. The dredged material is typically dewatered on the haul barge using best management practices (BMPs), such as sideboards for bulk containment and filter fabric and drainage systems to limit turbidity releases to the waterway. The dredged material would be moved in the haul barge to a waterfront location for offloading, possible additional dewatering, and transport to a selected disposal facility.

Conventional dredging methods advance each dredge cut at a constant dredge elevation within a discrete area. Dredging of sloped areas is normally completed with a series of stair-step cuts. The removal of a sloping layer is thus achieved by completing a series of horizontal bench cuts into the slope. The actual dredging pattern for slopes would be established by the selected removal action contractor to match the capabilities of the dredging equipment.

Hydraulic dredging is not considered practicable for this removal action because of the significant volume of water generated by the method, the relatively small size of the project, and the presence of debris. If hydraulic dredging were used, a comparatively large processing site would have to be developed nearby to dewater the dredge spoils before transporting the solids to a disposal facility. Development of a processing site would substantially raise costs and pose implementability concerns. Additionally, the presence of significant debris in Slip 4 would plug and/or damage the dredge, reducing efficiency, resuspending more material into the water column, and generating greater amounts of process water, increasing costs, extending schedules, and requiring adjunct mechanical dredging to remove the debris.

Diver-operated smaller hydraulic dredges have been used for removing materials under or around piers, pilings, or in other under-structure places where conventional dredging equipment is unable to reach. While an advantage of this method is the ability to dredge in these otherwise unreachable locations, consideration must be given to the diver's limited visibility to be effective and the overall safety of the diver from physical hazards and from potentially being exposed to resuspended contaminants. As with other

hydraulic dredges, debris limits the effectiveness of the dredge, and managing the large quantities of wastewater poses implementability concerns and raises costs.

As part of the design process, BMPs will be defined to reduce the potential for sediment resuspension and reduce water quality impacts during dredging. The selected contractor will be required to include BMPs in their remedial action work plan submitted to EPA for review and approval, and shared with the public.

4.3.2 Evaluation

Excavation and mechanical dredging technologies are effective, implementable, and cost-effective, and are retained as components of active remediation alternatives. Mechanical dredging is favored over hydraulic dredging at Slip 4 for the following reasons:

- **Disposal.** Mechanical dredging is best suited to landfill disposal because it avoids the addition of large volumes of water associated with hydraulic dredging.
- **Debris.** A mechanical dredge is more capable of handling the variety of debris that can be associated with an industrial site dredging project, especially when compared to a small (8- to 10-inch pipeline) hydraulic dredge that might be used for a project the size of Slip 4.
- **Water Management.** Mechanical dredging generates much less water than hydraulic dredging. The size of the upland facility and infrastructure required to manage the water associated with even a small hydraulic dredge would be considerable, and the local sewer system may not be able to handle the dewatering process.
- **Equipment Availability.** Mechanical dredging is completed with common marine/upland construction equipment, while hydraulic dredging requires dedicated, specialized equipment. There are more equipment options and a greater number of local contractors who are experienced with mechanical dredging.

Hydraulic dredging is rejected based on limited effectiveness in the presence of debris, and implementability and cost concerns associated with the required upland dewatering facility. Diver-operated hydraulic dredging is not considered practicable for this project due to these same concerns, in addition to concerns over the substantially increased risk to workers during the cleanup.

4.4 CONTAINMENT

4.4.1 Description and Applicability

Capping is an applicable containment technology for the Slip 4 removal area. Conventional sand caps and armored caps are applicable, and would be designed

according to site-specific conditions using established EPA and USACE design procedures (USEPA 1998). Other cap technologies described in the CTM include composite caps and reactive caps; these are specialty capping technologies that are typically applied for unique site conditions (such as presence of NAPL or high concentrations of highly soluble contaminants). Composite caps and reactive caps are not required for, or applicable to, Slip 4 conditions.

Cap material for Slip 4 would be obtained from established upland borrow sources. Consistent with CWA 404 requirements, the capping material would be evaluated to verify that it is “clean”—that is, suitable for in-water use. The evaluation would include consideration of physical and chemical properties of the material, as appropriate. All cap materials would have chemical concentrations below the SQS.

The configuration of caps and final cap materials, including armoring requirements, would be determined in design. Armored caps are required where erosive forces (i.e., shear stresses) on cap particles would be sufficient to move typical sand cap particles. Areas of Slip 4 with erosive forces that would likely require armoring include:

- Bank caps in Zones 3, 4, and 5, where even minor wave action on steep intertidal slopes creates high shear stresses. (Armoring may also be required on the banks to improve overall stability of the existing slopes.)
- Mudflat areas near the head of Slip 4, where outfall flows at low tide can create channel flow with high shear stresses.
- Areas near vessel operations, where propeller wash flows across the cap surface.

As discussed in Section 5, different cap materials and configurations would be needed in different areas under the various alternatives. The final configuration of the cap (including thicknesses and materials) will be established in the removal design.

As described for removal technologies, caps can be placed using land-based or waterway-based equipment. Capping of banks and portions of the head of Slip 4 (above approximately 0 to +4 feet MLLW) would likely be completed with land-based earthmoving equipment (excavators, front-end loaders, and dump trucks). Clean capping material would be imported to the site in dump trucks or on barges, and then placed as engineered fill over the impacted soil and sediment. Placement of cap material in-the-dry allows equipment operators to see where the capping material is being placed to ensure that the required coverage and material thickness is achieved. However, use of barge-mounted equipment is often more practicable, and numerous contractors in the region are experienced in the successful placement of caps on banks and in waterways using floating equipment.

In areas below 0 feet MLLW (the majority of the area within the Slip 4 removal boundaries), capping would be accomplished with floating equipment similar to that

used for mechanical dredging. The dredge would use a bucket to collect capping material from a haul barge and would spread the material on the bed of the waterway. In some areas, the placement would have to be timed to take advantage of periods of moderate to high tides in order to provide required flotation for the equipment (5- to 15-foot draft depending on specific equipment).

Most of the submerged area is open to access by conventional floating equipment. However, the area underneath the Crowley pier cannot be accessed with a derrick. A barge-mounted excavator or a conveyor would likely be used to place under-pier cap material. Due to limited overhead clearance, specific equipment selection and timing of the work with the tides would be critical.

4.4.2 Evaluation

Conventional sand caps and armored caps are effective, implementable, and cost-effective, and are retained as components of active remediation alternatives.

4.5 TREATMENT

The CTM (RETEC 2005) identified several treatment technologies deemed to have potential applicability for site-wide cleanup in the LDW. These include incineration and alternate treatment methods including soil washing and high-temperature thermal desorption. These technologies are discussed below and evaluated for their applicability to the Slip 4 removal action. Table 4-1 summarizes some of the general advantages and disadvantages of applying these treatment technologies for this early action.

4.5.1 Incineration

4.5.1.1 Description and Applicability

Incineration uses high temperatures, (870–1,200°C or 1,600–2,200°F) to volatilize and combust (in the presence of oxygen) organics in hazardous wastes. Auxiliary fuels are often employed to initiate and sustain combustion. Incineration can potentially occur at fixed, permitted facilities located out of state or at an onsite mobile unit.

4.5.1.2 Evaluation

Effectiveness: The destruction and removal efficiency for properly operated incinerators exceeds the 99.99 percent requirement for hazardous waste, and incinerators can be operated to meet the 99.9999 percent requirement for PCBs. However, some short-term and long-term residual risks may be associated with formation of dioxins and furans as a combustion by-product of the PCBs. Incineration is generally not effective for inorganic contaminants. Off-gases require treatment, and the combusted soils require disposal and potentially additional treatment. Short-term risks to local communities associated with incineration are managed through the requirements of the incinerator's operating permits.

The processed soil can constitute a significant percentage of the original feedstock (by volume) and must still be disposed of, most likely in a solid waste landfill. This type of processing does little to reduce the impact on landfill capacity and would require additional waste transport and handling steps (added short-term risk). In summary, incineration can effectively treat PCBs but may not effectively treat inorganics or substantially reduce disposal requirements.

Implementability: Siting and permitting (or meeting substantive permit requirements) of a mobile incinerator in the LDW vicinity would present substantial administrative feasibility concerns and is not considered implementable in the time frame of this NTCRA. Fixed incinerators licensed for PCBs are not available in the region. Therefore, incineration would require transporting waste over significant distances to commercially permitted facilities located in Utah, Arkansas, or Texas. TSCA requires that PCB-contaminated soil with concentrations equal to or greater than 500 mg/kg DW be treated using a TSCA-approved incinerator. However, existing data indicate that these concentrations are not present at Slip 4.

Cost: Incineration technology has the specific shortcomings of long haul distances and high cost and is typically applied only to those materials for which it is mandated under TSCA, where alternate disposal or treatment methods for materials containing lower concentrations of PCBs are not allowed. The technology is not cost-effective compared to direct land disposal.

In summary, incineration is not retained for further consideration as a treatment alternative for the Slip 4 removal action for the following reasons:

- Onsite incineration is not implementable in the time frame of the NTCRA.
- Offsite incineration is potentially effective in treating PCB-containing material; however, additional short-term risks are associated with the long transport distances, and the material would still require landfilling.
- Offsite incineration is not cost-effective compared to landfilling. The incremental costs of incineration are substantial and disproportionate to any benefits gained by the treatment.

4.5.2 Alternate Treatment Methods

4.5.2.1 Description and Applicability

The feasibility and cost-effectiveness of sediment treatment depend on a number of factors, including the quantity and physical characteristic of material to be treated over time, contaminant types and concentrations, the target post-treatment contaminant concentrations, and the potential end uses and marketability of the treated material. Based on the demonstrations in the New York/New Jersey harbor region (Wargo 2002)

that were supported by large experimental technology grants, sediment treatment appears to have the potential to become a viable alternative for sediments in the future. However, the total cost and overall technical and administrative feasibility of treatment must first approach the cost and feasibility of the disposal alternatives (USACE 2003). The local market for beneficial reuse of treated sediment originating from Superfund cleanup sites is anticipated to be very limited, and placement of treated materials back into the Slip 4 removal area is not considered to be a practical option due to timing constraints and anticipated residual concentrations.

Alternate treatment technologies specifically targeting PCB and other organic contaminants in excavated/dredged materials are identified in the CTM (RETEC 2005). These included advanced soil washing and high-temperature thermal desorption (HTTD).

4.5.2.2 Evaluation

The effectiveness, implementability, and cost of soil washing and HTTD are evaluated below. Additional analysis of the technical and policy considerations related to the use of Biogenesis™ advanced soil washing process for the treatment of contaminated sediments dredged from the LDW was recently summarized in a technical memorandum (RETEC and Integral 2005). This memorandum concluded that this process is not viable for the early action sites because its effectiveness is unproven for Slip 4 sediments, it would be difficult to implement and would delay cleanup, and is not cost-effective given current market conditions in the Northwest.

Effectiveness: Advanced soil washing and HTTD have limitations on their effectiveness for particular soil types. For example, soil washing and thermal desorption are less effective at removing contaminants from fine soil particles (silts and clays). Slip 4 soils are expected to contain a significant percentage of fines (averaging greater than 50 percent). It is unknown whether this fines fraction could be sufficiently cleaned to overcome the strict institutional barriers to any beneficial reuse, such as disposal of treated materials within the aquatic environment or uncontrolled use in upland soil products. Therefore, treated material would likely require landfill disposal.

Advanced soil washing has never been implemented full-scale and limited pilot-scale data are available. The pilot-scale tests have limited comparability to the Slip 4 soil conditions. For example, the maximum reported PCB concentration in untreated sediments tested by Biogenesis™ is 0.3 mg/kg for a pilot-scale project completed in New Jersey. PCB concentrations in sediments removed from Slip 4 are estimated to average approximately 10 to 12 mg/kg. At the New Jersey pilot test, treated sediment had grain size of 52 percent silt and 42 percent clay. This grain size is significantly finer than the Slip 4 sediments. Although the vendor claims that a 95-percent reduction of PCB concentrations is feasible, the results of the treatment as published on the website resulted in only 45 percent reduction of PCB concentrations. This percent reduction would not

result in treated Slip 4 sediments being below SMS criteria. Finally, the vendor has not been able to provide complete mass balance information for PCBs from the previous testing, and it is not known how much of the PCBs would simply be transferred to other waste streams such as sludges and wastewater (RETEC and Integral 2005). Overall, the effectiveness of this technology for the Slip 4 site would require evaluation in a pilot treatability study that would delay the cleanup and still not resolve all the concerns with implementability or cost-effectiveness. It is noted that a full-scale demonstration project of this technology began in December 2005 for the Ports of New York/New Jersey (Biogenesis 2005), and this trial may provide more operational data on the BioGenesis™ process.

HTTD has been used successfully at other sites with similar contamination. For example, sediments with greater than 500 ppm PCBs from the Waukegan Harbor site in Illinois were successfully treated with a high removal efficiency (RETEC 2005). However, Slip 4 soils have much lower initial PCB concentrations, and the removal efficiency for Slip 4 sediments is unknown. Air emissions from the Waukegan Harbor site met the TSCA 99.9999 percent destruction removal efficiency (DRE) stack emission requirement for final destruction of PCBs (RETEC 2005). However, HTTD operates at lower temperatures than TSCA-approved incinerators, and can result in only partial destruction of PCBs and the generation of partially oxidized, highly toxic byproducts such as dioxins. Incinerators specially permitted to accept PCBs have very strict monitoring requirements for their process and emissions, beyond those normally practiced at other facilities. Similar monitoring requirements would apply to HTTD to guarantee that the PCBs are being effectively treated (destroyed) and that potential health impacts to the surrounding community are adequately addressed. As with advanced soil washing, HTTD would require treatability testing to evaluate its effectiveness for Slip 4 soils.

Implementability: Fixed facilities for HTTD or soil washing are not available in this region. Siting and permitting (or meeting substantive permit requirements) of these facilities in the LDW vicinity would present substantial administrative feasibility concerns and are not considered implementable in the time frame of this NTCRA. Administrative feasibility is of particular concern with HTTD, given off-gas emission control requirements similar to those for incineration.

There are significant potential liability issues with offsite re-use of soils containing residual levels of PCBs and other contaminants. Onsite re-use is not considered administratively implementable due to timing constraints, site logistics, and concerns over reintroducing contaminants to a sensitive aquatic habitat. Compared with landfill disposal, most potential reuse options (either onsite or offsite) would have the potential for greater long-term human and/or environmental exposures to residual concentrations of contaminants in the treated material. In the case of soil washing, residual levels of treatment chemicals may also create toxicity. Therefore, any reuse option would require careful evaluation (and potentially permitting) by regulatory agencies and other

stakeholders. Such evaluations could require considerable time and effort. These concerns coupled with the short time frame for the Slip 4 early action make it likely that most or all of the treated soil would still require disposal at a permitted RCRA landfill. The other waste streams (wastewater and sludges containing PCBs from soil washing, or gasses from thermal desorption) also require treatment or disposal and result in additional releases of contaminants into the environment. Additional elements impacting implementability include:

- **Testing and Design Requirements.** Treatability testing would be required for evaluating the effectiveness of these technologies for the Slip 4 soils and optimizing the process for these soils. The treatability testing process, including sampling, analysis, treatability testing, and reporting, would require roughly 6–24 months of planning time (see text box on treatability testing, below). The design, contracting, and mobilization of this technology could begin only after 1) the appropriate testing was planned, completed, and reported; 2) the results were evaluated by regulatory agencies; and 3) the testing results were both conclusive and favorable. It is estimated that the design, contracting, and mobilization of this technology would then require an additional 6–24 months before the removal action could begin. Overall, this process would add several months or years to the project schedule. Given the limited in-water construction season, testing and design requirements would delay the removal action by a minimum of one year and potentially up to three years. The goal of this NTCRA is to provide early risk reduction in an accelerated cleanup process. Therefore, in the context of the time frame of this removal action, construction could not be implemented beginning in 2007 as currently planned, and these technologies are not readily implementable.
- **Need for Storage and Pre-processing.** Soil washing and HTTD have limited throughput and cannot treat excavated or dredged materials as fast as they are generated. This limitation necessitates additional stockpiling and rehandling. Bank soils and mudflat sediments contain considerable debris. Both soil washing and thermal desorption require that large debris first be screened out, with only the soil particles being processed. These pre-processing and storage requirements add complexity and cost to the project, increase the overall scope of the treatment facility, and can result in project delays associated with logistics.

Treatability Testing Approach and Timing

To evaluate the application of treatment technologies to particular sites, it is essential to conduct laboratory or pilot-scale tests on actual wastes from the site. The general approaches for treatability testing are described in EPA (1992) guidance and summarized below:

The extent of required testing is dependant on the degree to which the technology has been implemented in full-scale applications with materials and contaminants similar to the site conditions. The testing can be bench-, pilot-, or full-scale. Bench-scale tests are small-quantity, batch simulations of a continuous large-scale process. Pilot-scale tests are typically onsite and treat on the order of 1 to 100 tons of material. In general, a successful bench-scale test yields qualitative data and needs to be followed by a pilot- or full-scale test to yield quantitative, real-world cost and performance data. This is particularly important for sediments, which are a complex and heterogeneous matrix; sediments often contain high silt and/or clay content, significant organic content, salinity, debris, high water content, and multiple organic and inorganic contaminants. Considerable time is required to plan, execute, and evaluate the testing results. General steps in the process include:

Bench-Scale Testing (6–18 months):

- Identify and contract with vendors and laboratories. Public agencies may need to contract with multiple vendors to satisfy contracting laws.
- Design the study—plan sample collection for representative/worst-case matrix conditions, identify treatment goals, design the study to evaluate the effects of multiple parameters (e.g., analysis of variance design).
- Identify QA requirements.
- Develop study work plans and obtain agency approvals.
- Collect the field samples.
- Conduct the testing by the vendor, analyses by labs, and obtain raw data
- Evaluate and report the data.

Pilot-Scale Testing (12–24+ months):

Includes all of the bench-scale considerations, plus:

- Arrange logistics of siting a treatment system (land, utilities, permits).
- Contract with a construction contractor for removal of several tons of material from the water.
- Develop construction work plans, time the removal for fish windows, obtain all agency approvals and certification for in-water work, potentially including ESA considerations.
- Mobilize construction and treatment contractors.
- Operate the treatment system.
- Intensively monitor performance.
- Vary process parameters to evaluate/optimize performance.
- Evaluate and report the data.

Successful completion of these steps allows planning to begin for the full-scale design.

- **Need for Residuals Management.** Soil washing (and operation of associated storage facilities) creates substantial quantities of wastewater that requires management and additional treatment, either onsite or offsite. The Biogenesis™ trial at the New York/New Jersey Harbor demonstration generated 298,000 gallons of wastewater in the treatment of 700 cubic yards (cy) of sediment (Wargo 2002). Wastewater management requirements add complexity and cost to the project, increase the overall scope of the treatment facility, and can result in project delays associated with logistics. For example, wastewater would require treatment and analysis prior to disposal or discharge; discharge to the King County wastewater treatment system may not be viable due to limited sewer capacity; discharge to the waterway would require permitting or otherwise meeting the substantive permit requirements; and the wastewater treatment system itself would require treatability testing to design the system and ensure that contaminants are effectively reduced to accepted levels in the wastewater discharge.
- **Lack of Established Facilities.** There are no established treatment facilities in the region that routinely process PCB-contaminated materials. Consequently, a significant piece of upland property would be required to erect and operate a mobile plant to accommodate material pretreatment and handling processes; this would likely require more land than is available adjacent to the site. The EE/CA for the T-117 early action estimated that greater than 1 acre of land would be needed (Windward et al. 2005). Because this land is not currently available adjacent to Slip 4, an alternate processing site would likely need to be established and would require additional waste handling and hauling, increasing the risk of short-term re-contamination and exposure. The processing site may also require permitting, which may not be feasible in the time frame of this NTCRA. While treatment systems may exist in other cities or states, waste would need to be hauled over long distances to be processed and residuals re-loaded and hauled to a final disposal site (i.e., landfill).

Cost: Experience has shown that mobilization and setup of a project-specific treatment facility entails a significant initial cost. The treatment plant must process a significant volume of material to recover the fixed mobilization and setup costs. This may not be possible for the Slip 4 site, where the various removal action alternatives consider sediment/soil removal volumes ranging from 8,100–40,000 cy. Taken together with high implementation and pilot testing costs, these technologies are not cost-effective for this particular site-specific application.

In summary, HTTD and soil washing are not retained for further consideration as treatment alternatives for the Slip 4 removal action for the following reasons:

- Their effectiveness on Slip 4 sediments is uncertain and requires treatability testing.

- Established offsite facilities are not available regionally.
- Given the testing, design, and substantive permit requirements associated with evaluating performance and establishing treatment facilities, these technologies are not implementable in the time frame of the NTCRA.
- Treated material would still require landfilling.
- Treatment is not cost-effective compared to landfilling. The incremental costs of treatment are substantial and disproportionate to any benefits gained by the treatment.

4.6 DISPOSAL

4.6.1 Description and Applicability

Disposal of excavated or dredged material could potentially occur at either established and permitted offsite facilities or at a constructed onsite disposal facility.

4.6.1.1 Offsite Disposal

Disposal of excavated and dredged material in permitted TSCA or RCRA Subtitle D landfills meets all state and federal requirements and uses reliable and demonstrated technologies. It is readily implemented and minimizes the amount of upland area and time required for material handling and loading. Landfilling is routinely approved by EPA and the State of Washington for disposal of PCB-contaminated solids. Disposal sites must be evaluated and approved by EPA before they are selected to receive materials originating from CERCLA sites. EPA's review includes assessing the site's compliance with TSCA and/or RCRA permits and governing regulations. This agency evaluation of any proposed landfill disposal site will be consistent with the Off-Site Rule (40 CFR 200.440). This rule is intended to avoid having CERCLA waste contribute to present or future environmental problems by directing these waste to sites determined to be environmentally sound.

Existing sampling information indicates most or all of the excavated and dredged material would have total PCB concentrations less than 50 mg/kg DW, and is suitable for placement in a RCRA Subtitle D solid waste landfill. One sample location (SL4-6A, 0–2 foot depth) had a total PCB concentration greater than 50 mg/kg DW. Material excavated from this area would be segregated and the excavated material sampled to determine disposal requirements. Should the excavated material exceed 50 mg/kg DW PCBs, it would be disposed of in a permitted TSCA landfill.

Transportation of excavated/dredged material to the landfill would be by truck, rail, or some combination depending on the selected removal action alternative and the contractor's specific construction approach. To the extent that truck transport is used,

hauling of material from the removal area to the disposal site would result in some increased truck traffic on East Marginal Way and other arterial streets.

Additional information on specific landfills is provided in the following subsections.

RCRA Subtitle D (Solid Waste) Landfills

Dredged material that satisfies the solid waste regulations could be disposed of in Subtitle D RCRA commercial landfills. Two upland regional landfills have established services to receive dredged sediments and low-concentration contaminated soil (PCB concentration <50 mg/kg DW): Roosevelt Regional Landfill near Goldendale, Washington, and Columbia Ridge Landfill near Arlington, Oregon. These sites are licensed as Subtitle D (RCRA) commercial landfills in the states in which they operate, and both have the ability to receive wet dredged sediments delivered to the landfill by rail.

The Regional Disposal Company (RDC) operates the Roosevelt Regional Landfill. During 2004, Tau, LLC handled dredged material at a barge-to-rail loading facility at the Port of Seattle, for disposal at the Roosevelt Regional Landfill. RDC is currently looking for a new property to provide barge-to-rail transloading in the future.

Waste Management Inc. operates the Columbia Ridge Landfill. In 2004, Waste Management completed significant upgrades at the landfill to allow offloading of rail cars loaded with soil and dredged material. During 2004, Waste Management offloaded barges and loaded railcars with dredged material at the Lockheed site on Harbor Island for delivery to and disposal in the Columbia Ridge landfill. Waste Management has indicated that its intention is to have a regional transloading facility operating in the future (RETEC 2005).

During design, one or more transloading facilities will be identified based on their status at that time. Dredged material could be delivered to the identified sediment offloading facility via barge, while upland excavated material could be transported by barge or truck to a transfer facility operated by a landfill.

TSCA Landfills

As discussed above, a small area of sediments near the head of Slip 4 may contain PCBs at concentrations equal to or above 50 mg/kg DW and, if landfilled, must be placed in a hazardous waste landfill specially designed and permitted under TSCA to receive such materials. TSCA-regulated solids containing PCBs at concentrations equal to or exceeding 500 mg/kg DW are prohibited from land disposal under TSCA and are typically incinerated. However, site data indicate these concentrations should not be encountered. Landfills meeting these requirements and effectively providing disposal services for TSCA-regulated solids containing PCBs are discussed below:

- **Chemical Waste Management of the Northwest.** A subsidiary of Waste Management Inc., Chemical Waste Management operates a facility located at Arlington, Oregon. This Subtitle C secure landfill facility provides land disposal of soil and debris contaminated with PCBs at concentrations exceeding levels allowed in regional solid waste landfills. The Arlington site is accessible from Seattle by rail.
- **U.S. Ecology.** A subsidiary of the American Ecology Corporation, U.S. Ecology operates chemical waste landfills permitted under TSCA for accepting PCB-contaminated materials at Grand View, Idaho, and Beatty, Nevada. The site at Grand View is accessible by rail. The Beatty facility is located 100 miles northwest of Las Vegas, Nevada.

4.6.1.2 Onsite Disposal

Onsite disposal involves consolidating the removed material in a containment cell constructed within the project boundaries. The CTM identifies several onsite disposal technologies as potentially applicable for LDW sediments (RETEC 2005). Upland onsite disposal involves placing removed material into a lined and capped embankment constructed away from the shoreline. In-water onsite disposal involves placing dredged material into a cell constructed in the aquatic environment. One example of in-water disposal involves placing dredged material into a submerged pit, which is then covered by a cap, referred to as confined aquatic disposal (CAD). Another example of in-water disposal involves placing dredged material into a diked cell extending from the shoreline that is then capped to create new uplands. This is referred to as a confined disposal facility (CDF) or a nearshore confined disposal (NCD) facility. Implementation of onsite disposal technologies normally requires extensive site evaluations and design studies. Issues to be addressed include contamination transport and containment, long-term stability, land-use regulations, comparison to alternate technologies, and public acceptance.

4.6.2 Evaluation

Offsite disposal at permitted landfills is considered effective, implementable, and cost-effective for Slip 4 sediments.

Onsite disposal is potentially effective, but is not considered implementable or cost-effective for the Slip 4 NTCRA based on the following factors:

- **Schedule**—The time required to fully investigate, design, and implement an onsite disposal technology can be several years, which is too long and not appropriate for a NTCRA.
- **Land Availability**—There is no land available within the removal boundary to construct an upland containment cell. Properties surrounding Slip 4 are used for

industrial purposes. Relocation of dredged material into the upland would also cause unacceptable changes to the topography that would significantly limit the future productive use of these properties.

- **Need for Mitigation**—Construction of a CDF would represent a net loss of aquatic habitat and would require mitigation under CWA Section 404. Property would have to be acquired for the CDF as well as for a mitigation site that would provide appropriate replacement of lost aquatic acreage and habitat function.
- **Alternate Technologies**—CWA Section 404 limits the construction of in-water disposal sites to situations where there is no other practicable alternative. Since offsite disposal is a currently available practical alternative for the Slip 4 EAA, in-water filling is not being considered for the project.
- **Cost**—Development of an onsite disposal facility would require significant expenditures for evaluations, design, permitting, construction, and potentially land acquisition. To be cost-effective, these high development costs need to be spread over large volumes (100,000 cy plus) of disposed material, or constructing the facility needs to result in other benefits such as the creation of new industrial uplands or new habitat. Because of the relatively low volume of material generated by the Slip 4 removal action (8,100 to 40,000 cy), the creation of onsite containment is not considered to be cost-effective as compared to offsite disposal.

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5 IDENTIFICATION AND ANALYSIS OF REMOVAL ACTION ALTERNATIVES

This section presents a brief description of the removal alternatives and evaluates each alternative with regard to effectiveness, implementability, and cost.

In Section 4, technologies within the general response action categories of Institutional Controls, MNR/ENR, Removal, Containment, and Disposal were determined to be potentially applicable to the Slip 4 removal action. These technologies have been assembled into a set of removal alternatives that range from an emphasis on containment (with minimal removal) to an emphasis on removal (with minimal containment). The primary information that was considered during development of the alternatives includes:

- The nature and extent of contamination found in the sediments and banks
- Physical features such as outfalls, bulkheads, Crowley's pier, and existing bathymetry
- Dredging history
- Land use considerations (including property ownership, the presence of Crowley's permitted berthing area, and tribal treaty fishing rights)
- Substantive requirements of CWA Section 404, including a goal of no net loss of aquatic habitat to avoid the need for mitigation
- Slope and structural stability considerations.

Four alternatives have been developed for the Slip 4 removal area based on the RAO identified in Section 3 and the technologies that were carried forward from the initial screening of technologies in Section 4. Each of the alternatives addresses the approximately 3.6-acre area within the removal action boundaries defined in Section 3. The alternatives are summarized below:

- **Alternative 1** is based on a containment approach, primarily involving capping of contaminated sediments in place while minimizing excavation and the need for offsite disposal. Prior to capping, limited excavation and offsite disposal would occur at the head of the slip to accommodate outfall flows and on banks to ensure no net loss of aquatic habitat. Derelict piling and debris would be removed. Engineered sediment caps would be constructed over the entire Slip 4 removal area, including engineered slope caps on the affected banks. Portions of the cap would be thickened and graded to expand and enhance shallow subtidal and intertidal habitat. Alternative 1 limits Crowley's potential use of a permitted

berthing area in the inner portion of the slip. As compensation, the City of Seattle is willing to purchase the affected property from the landowner if this alternative is selected.

- **Alternative 2** includes targeted removal of contaminated sediments at the head of the slip, along with capping. The objectives of dredging would be to remove near-surface material with the highest concentrations of contaminants, minimize changes to mudflat habitat at the head of the slip, and accommodate outfall flows. Derelict piling and debris would be removed, and banks would be excavated to ensure no net loss of aquatic habitat. Engineered sediment caps would be constructed over the entire Slip 4 removal area, including engineered slope caps on the affected banks. Portions of the cap would be thickened and graded to expand and enhance shallow subtidal and intertidal habitat. Alternative 2 limits Crowley's potential use of a permitted berthing area in the inner portion of the slip. As compensation, the City of Seattle is willing to purchase the affected property from the landowner if this alternative is selected.
- **Alternative 3** includes dredging in the head and inner berth areas of the slip, along with capping. The objectives of dredging would be to remove near-surface material with the highest concentrations of contaminants, minimize changes to mudflat habitat at the head of the slip, accommodate outfall flows, remove contaminated material in the inner berth to re-establish historically permitted navigation depths (-15 feet MLLW), and attain a clean dredged surface in the inner berth. The dredging would be limited in scope to minimize impacts to adjacent structures and outfalls. Derelict piling and debris would be removed, and banks would be excavated to ensure no net loss of aquatic habitat. Engineered sediment caps would be constructed in the areas outside the inner berth, including engineered slope caps on the affected banks.
- **Alternative 4** includes the greatest amount of dredging within Slip 4 among the four alternatives. The overall objective of dredging would be to remove all contaminated material exceeding the SQS where reasonably feasible, but the dredging would be limited in scope to minimize impacts to adjacent structures and outfalls. As with Alternative 3, this alternative would re-establish historically permitted navigation depths in the inner berth. Derelict piling and debris would be removed, and banks would be excavated to ensure no net loss of aquatic habitat. To minimize habitat disturbances by the deepening, the areas outside the inner berth would be backfilled with clean material. In areas where dredging could not remove all contaminated materials, the backfill would be designed to function as a cap. Engineered slope caps would also be constructed in bank areas.

In developing the removal alternatives, consideration was also given to a "maximum feasible removal" alternative, involving removal of most or all of the contaminated sediments within Slip 4, with an objective of avoiding the need for capping. Site

limitations (including slope stability; structural stability of piers, outfalls, and bulkheads; and depth of contamination) would require extensive engineering measures to accomplish complete removal of all contaminated material. These measures would include:

- Sheetpile retaining walls would need to be constructed along the banks in Zones 2, 3, and 5 to prevent slope failures into the excavation. Alternatively, more extensive bank excavations could be extended into upland areas to establish stable temporary slopes, and additional backfill placed to re-establish upland property.
- A replacement sheetpile bulkhead would need to be installed along the Zone 4 shoreline to prevent the existing bulkhead from a rotational failure into the excavation. The sheetpile bulkhead would be installed immediately inboard of the existing bulkhead, and the existing bulkhead would then be removed and disposed of.
- Engineering measures, such as piling and pier structures, would need to be constructed to support the major outfalls at the head of the slip during excavation. Alternatively, the outfalls could be demolished and rebuilt.
- Diver-operated hydraulic dredging of the under-pier area would be required to attempt to fully remove under-pier sediment deposits. Diver-operated hydraulic dredging is potentially the most effective approach for cleanup of a hard face; however, loose rock causes inefficient removal, and debris may cause unsafe conditions (USEPA 2005a). The costs of mobilizing the required equipment, personnel, and handling facilities would be substantial, and residuals exceeding cleanup levels still may be present in the interstices of the riprap.
- Extensive confirmation sampling and contingency measures (such as overdredging) would be required to ensure complete removal and manage dredge residuals during construction.
- Capping would still be required on the Zone 3 and Zone 5 banks and in any areas where contingency measures failed to remove all contaminated sediments.
- To minimize habitat loss caused by deepening, extensive backfilling would be required at substantial additional cost.

The total cost of such an alternative would be in the range of \$15–20 million. This approach would offer potential benefits with regard to long-term effectiveness because most of the contaminated materials would be removed from the site. However, it would have greater short-term impacts during construction, could require two construction seasons to implement, and would have substantially greater incremental costs than other, equally protective alternatives. The incremental cost of this approach is considered to be

substantial and disproportionate to any benefits, and therefore the “maximum feasible removal” approach was not carried forward.

A no-action alternative was not considered for the Slip 4 removal area because it would not satisfy the removal action objectives and would not be protective of human health and the environment.

In the following subsections, the following criteria are used in the evaluation of the four alternatives (USEPA 1993):

- Effectiveness
 - Overall protection of human health and the environment
 - Achievement of RAOs
 - Compliance with ARARs
 - Reduction of toxicity, mobility, or volume through treatment
 - Short-term effectiveness
 - Long-term effectiveness and permanence
- Implementability
 - Technical feasibility
 - Availability
 - Administrative feasibility
- Cost
 - Capital cost
 - Present worth of long-term monitoring and maintenance
 - Total present-worth cost.

5.1 ALTERNATIVE 1—CAPPING AND HABITAT ENHANCEMENT

5.1.1 Description of Alternative 1

Alternative 1 is based on an approach emphasizing containment of contaminants by capping the sediments in place. The capping would affect Crowley Marine Service’s navigation use of the inner berth, and hence the City would purchase a portion of Slip 4 from Crowley. Prior to capping, limited sediment removal and offsite disposal would occur. The extent of excavation would be based on achieving the following objectives:

- Accommodate outfall drainage
- Ensure no net loss of aquatic habitat

- Improve conditions of bank areas in preparation for capping (including improving slope stability, removing debris, and preparing a subgrade for cap placement)
- Consider improvements to intertidal habitat in locations where the City will own the bank and adjacent upland areas.

Excavation at the head of the slip would be limited to a small area near outfalls, and designed such that the final cap surface allows proper drainage of the existing outfall flows. An engineered sediment cap would be constructed over the entire Slip 4 removal area, including engineered slope caps on the Zone 3, 4, and 5 embankments. The cap would be engineered to withstand outfall scour and other erosive forces. Portions of the cap would be thickened and graded to expand and enhance shallow subtidal and intertidal habitat. Under Alternative 1, the City and King County have proposed certain improvements to intertidal habitat, and EPA understands that these improvements are considered relatively small increases in cost and effort relative to the overall alternative.

These elements are depicted conceptually in Figures 5-2 through 5-5 and described in further detail below.

Purchase of Land in the Slip 4 Removal Area

Crowley Marine Services currently owns the majority of the submerged land in Slip 4 and has a historical navigation use of the inner berth area. Capping in the inner berth area would create an area too shallow for the vessels Crowley might berth here. Because the capping actions under Alternative 1 would limit Crowley's historical and permitted use of their property, Crowley would require compensation for this lost use. (This compensation could involve purchase of an easement, purchase of the land, or other options—purchase of the land is assumed for the purposes of this EE/CA.) Crowley is willing to sell the affected property to the City of Seattle. The area that the City would purchase (or otherwise acquire rights to) is shown in Figure 5-1, and includes the bed of the slip as well as two small upland areas adjacent to the head of the slip. If Alternative 1 was selected, the City would proceed with negotiations for a purchase and sale agreement with Crowley for this land. The negotiations may include a lot line adjustment in the under-pier area so that no capped areas would remain in Crowley's ownership.

Piling and Debris Removal

Existing derelict, creosote-treated piling, failed bulkheads, and debris would be removed within the removal action area prior to dredging and capping. This material is present in the Zone 2 and Zone 3 shoreline areas, in the mudflat at the head of Slip 4, and the northern 100 feet of standing bulkhead in Zone 4. Piling would be removed intact, if possible, using either vibratory extraction or dead-line pull methods. Piling that can not be removed intact would be cut at or near the mudline. The piling removal would follow

procedures outlined in recent EPA (2005c) guidance. Some inert debris embedded in the mud would remain in place if it is determined that it would not affect the function of the cap. An estimated 400 tons of piling and debris would be removed and disposed of offsite.

Bank Excavation, Habitat Expansion, and Bank Capping

Soil data collected from borings along the shoreline indicated that the soil behind the bank is composed primarily of loose-to-medium-dense silty sand, with deposits of sandy silt. Cut slopes no steeper than 2 horizontal to 1 vertical (2H:1V) are defined for establishing the bank excavations. Steeper excavated slopes would likely require shoring or armoring to remain stable.

Approximately 300 linear feet of the Zone 3 bank, 100 linear feet of the Zone 4 bank, and 140 linear feet of the Zone 5 bank would be excavated shoreward an average of 3 feet to a 2H:1V slope, removing impacted soil and sediment, creosote-treated timbers and piles, debris, and other material. The excavation would extend from the top of the bank down to approximately 0 feet MLLW.

In portions of Zone 2 and Zone 3 near the head of the slip where the City would have ownership of the adjacent uplands, the bank excavation would be extended landward to improve and expand intertidal habitat. The excavation in these areas (covering approximately 250 feet of shoreline) would create a shallower slope (approximately 3.5H:1V) and approximately 0.06 acres of new aquatic habitat from existing uplands. This intertidal habitat expansion is shown in plan view on Figure 5-2 and on the cross section at Station 1+00 on Figure 5-3. Overall, approximately 7,300 cy of bank material would be removed under Alternative 1.

The exposed surface following excavation would be sampled to document chemical concentrations beneath the cap; these data would be used in assessing long-term monitoring requirements. The excavated banks would then be capped with an engineered slope cap with a nominal thickness of approximately 3 feet. The slope cap would typically consist of layers of filter material (an engineered sandy gravel), quarry spalls or riprap (for erosion protection and slope stability), and a surface layer of sand and gravel (for improved habitat quality). Specific cap materials would be determined in the design.

Outside the intertidal habitat expansion areas, the bank excavation and capping would be configured to avoid any net loss of aquatic habitat acreage. For the purposes of this EE/CA, the elevation +12 feet MLLW contour of the existing grade is generally used as the control line for maintaining aquatic habitat acreage, as illustrated on the cross sections for Alternative 1 (e.g., Station 2+00 on Figure 5-3). At this transect the +12 feet MLLW

contour of the cap matches the location of the +12 feet MLLW contour of the existing grades.

The actual configuration of the bank excavation and capping would be established during design. Caps would be designed in general accordance with applicable EPA and USACE capping guidance (USEPA 1998). The caps would be designed for long-term static and seismic stability. Seismic stability is a concern primarily for the slope caps constructed on the banks. For the purposes of this EE/CA, maximum cap slopes (2H:1V) and cap materials are described that are consistent with regional embankment designs that meet with modeled and proven seismic stability. During design, appropriate seismic design criteria will be developed, and slopes and/or materials may be modified to ensure seismic stability. Habitat design elements would be coordinated with the tribes and relevant federal and state agencies during the design process.

Existing sampling data (Parametrix 2005) indicate that the exposed bank surface to be capped may contain concentrations on the order of 0–830 mg/kg OC PCBs in Zone 3, 0–130 mg/kg OC in Zone 4 and 0–70 mg/kg OC PCBs in Zone 5. The slope caps would be designed to function as permanent caps, but would not preclude future upland removal actions if deemed necessary by Ecology in the future. A contingency plan will be developed during the removal design to respond to unanticipated conditions encountered during excavation, such as the presence of highly contaminated materials.

Under Alternative 1, excavation of the Zone 2 embankment is included only for the purpose of habitat expansion. The excavated portion of Zone 2 would be covered with slope cap materials for bank stabilization. Existing data from a single sample indicates the Zone 2 embankment outside the removal boundary is below the SQS. Predesign investigations will further assess the quality of the Zone 2 embankment material. Should portions of this embankment significantly exceed the SQS, the design may include additional removal and/or capping in Zone 2.

Excavation Within Slip 4

Under Alternative 1, approximately 700 cy of sediment would be removed near outfalls at the head of Slip 4 to accommodate a cap and to maintain proper drainage grades, as depicted on Figure 5-2. This sediment removal would likely be accomplished by excavation (as opposed to dredging), because the anticipated bottom elevation of the excavation would likely allow the work to be accomplished in-the-dry at low tides.

Five major outfalls are present at the head of Slip 4, as depicted on Figure 3-1. Three of the outfalls [the 72-inch I-5 SD, the 24-inch North Boeing Field SD, and the 60-inch King County Airport SD #3/PS44 EOF] would require little or no excavation prior to capping. The Georgetown flume is constructed at a lower elevation that will necessitate some excavation prior to capping. Limited excavation may also be needed to accommodate the

36-inch East Marginal Way PS EOF. The excavation(s) would be designed to accommodate a final cap surface that is free-draining at low tide. Details for excavating and capping around the outfalls, including any necessary temporary stabilization measures to protect the outfall structures, would be developed in the design.

Georgetown Flume Actions

The lowest segment of the Georgetown flume (approximately 370 feet of the 60-inch corrugated metal pipe upgradient from the outfall itself) is being further investigated as it is currently partially submerged in sediment, and substantial deposits of contaminated sediment could extend from Slip 4 up the flume for some distance. Sediment accumulations currently present within the Georgetown flume immediately upgradient from the outfall structure will be assessed during predesign investigations. Any significant accumulations would be removed either as part of this NTCRA or as a separate action by the City. Modifications to the outfall structure would be incorporated into the design, if modifications are determined to be necessary to ensure proper function.

Sediment Capping Within Slip 4

Engineered sediment caps would be placed throughout the Slip 4 removal area to physically and chemically isolate any affected sediments not removed by dredging. The specific cap configurations would be determined in the design, in accordance with EPA and USACE guidance (USEPA 1998). The caps would be designed for long-term seismic stability. The overall capping plan is depicted on Figure 5-2.

For the purposes of this EE/CA, a nominal 3-foot cap thickness is assumed for most areas based on regional experience at similar sites. However, for Slip 4, two site-specific design objectives have been identified that may warrant a thicker cap in portions of the site:

- **Protection of Shellfishing Treaty Rights.** Slip 4 is a usual and accustomed fishing ground for Native American tribes. To ensure that potential future shellfishing activities do not significantly disturb the cap or expose underlying materials, a thicker cap (up to 5-foot thickness) would be specified in lower intertidal areas. This would not apply to areas where cap armoring (required for erosion protection or slope stability) would otherwise protect against significant disturbances by shellfishing activities.
- **Enhancement of Shallow Subtidal and Intertidal Habitat.** Expansion and enhancement of shallow subtidal (-10 feet MLLW to -4 feet MLLW) and intertidal (-4 feet MLLW to +12 feet MLLW) elevations is a habitat conservation strategy for the Duwamish estuary (King County 2005). In addition, the Natural Resource Trustees have identified the elevation ranges of +4 feet to +12 feet as being particularly desirable for creation/expansion of upper intertidal marsh habitat.

Considering these goals, attention would be given to locations where modest changes in cap thickness can result in net area gains within these elevation ranges.

Given these two objectives, the cap thickness would be increased to up to 5 feet thick along the eastern portion of the slip, as generally depicted on Figures 5-2 and 5-4. The specific grading plan would be determined during the design phase, in coordination with the Natural Resource Trustees.

At the head of Slip 4, from Station 0+00 to Station 2+50, the cap would be appropriately graded and designed to resist erosive forces from outfall flows (including peak flows during extreme storm events) and allow proper drainage. Erosion protection requirements would vary by location. To manage potential erosive forces from outfall flows at low tides, the outfall flows would be directed into a shallow swale engineered into the cap.⁵ Within this swale, the cap would include a layer of coarser materials to resist erosive forces. Within the swale, the cap would typically consist of layers of filter material, overlain by quarry spalls or river rock, and a surface layer of sand and gravel. The swale itself may occupy roughly 0.1 acre. Outside of the swale, less armoring is expected to be needed.

From Stations 2+50 to approximately 7+00 (the subtidal removal area boundary), the cap would typically consist of sand or sandy gravel, and may include an armoring layer in certain areas as needed to resist erosive forces from propeller wash. The cap would extend under the Crowley pier to the edge of the riprap so that any potentially contaminated under-pier sediments are capped.

Bank areas in Zones 3, 4, and 5 would be capped as previously described, and cap material would also be placed on the excavated Zone 2 embankment for slope stabilization. The total volume of cap materials under Alternative 1 is approximately 27,000 cy.

Residuals Management

Excavation under Alternative 1 would be accomplished using BMPs to reduce the potential for resuspension and mobilization of contaminated sediments. However, during any dredging or excavation action, some disturbed, contaminated material often remains at the new surface—this material is referred to as “residuals.” Residuals can affect the dredged or excavated area as well as nearby surrounding areas. BMPs during

⁵ Relocation of the outfalls at the head of Slip 4 is not considered to be practicable. Relocating this established drainage infrastructure would likely require several million dollars and years of planning. Alternatively, extending the outfalls farther into Slip 4 (so that they discharge at subtidal elevations) would be very costly, would require extensive engineering measures to improve foundation soils, would result in more disturbance of contaminated sediments, and may create inspection and maintenance problems.

excavation (including completion of most of the excavation in-the-dry) would reduce the generation of residuals. The following paragraphs discuss how any remaining residuals would be managed after the excavation.

Under this alternative, none of the excavated areas would be left uncapped and the excavations are not necessarily designed to expose a clean surface. Also, most of the excavation areas are far removed from the southern boundary of the EAA, minimizing the possibility of fugitive residuals affecting offsite areas. Therefore, any residuals would be permanently contained by the planned capping which would occur after the excavation is complete. No additional contingencies or management actions (such as overexcavation to reach a clean surface) are required following the excavation. However, post-excavation samples would be collected on the exposed surfaces of excavated areas to document the nature of the material beneath the cap. It is possible that the excavations would remove all contaminated material on portions of the embankments, in which case the final cap may require a lesser degree of long-term monitoring and maintenance.

Confirmation samples would also be collected on top of all final cap surfaces and in the area immediately south of the subtidal removal boundary to verify compliance with the cleanup standards. Because capping involves minimal disturbance of existing bottom sediments, there is little potential for contaminant transport to areas south of the subtidal removal boundary, and the need for residuals management actions in this area is unlikely. However, the design will include provisions for residuals management actions south of the subtidal removal boundary, if needed.

Material Handling, Transportation, and Disposal

Dredged or excavated materials would be either loaded onto trucks onsite or loaded onto conventional barges and moved offsite. The material from barges would be offloaded to either rail cars or trucks at a rehandling facility in the project vicinity. One or more acceptable rehandling facilities would be identified in the design.

Existing sampling information indicates most or all of the excavated and dredged material would have total PCB concentrations less than 50 mg/kg DW and is suitable for placement in a RCRA Subtitle D solid waste landfill. One sample location (SL4-6A, 0–2 foot depth) had a total PCB concentration greater than 50 mg/kg DW. Predesign investigations may be conducted to determine if there is a definable area where PCB concentrations are greater than 50 mg/kg DW. If so, material excavated from this area would be segregated during construction (if practicable), and the excavated material would be sampled to determine disposal requirements.

Excavated and dredged material (including nonrecyclable debris) would be disposed of in a permitted TSCA or RCRA Subtitle D landfill that meets state and federal requirements for properly disposing of PCB-contaminated solids. The disposal site(s) would be

evaluated and approved by EPA before they are selected to receive materials originating from the site. Agency site review includes the site's compliance with TSCA and/or RCRA permits and governing regulations.

Some debris (e.g., concrete, metals) may be candidate material for recycling; this material would be segregated, cleaned, and evaluated for recycling at an approved facility.

Imported cap materials would be delivered to the site primarily by barge. The contractor may elect to deliver some import materials (such as for bank capping) by truck.

Construction Approach

The design will include plans and specifications that are primarily performance-based, with specific requirements for excavation and capping grades/tolerances, materials, environmental protection, and sequencing of the work. (General sequencing issues are discussed further in Section 6.2.) The contractor will be required to submit a remedial action work plan that details the proposed construction means, methods, and schedule. The contractor's work plan will be reviewed and approved by the City's Engineer and EPA.

To reduce resuspension and mobilization of contaminated sediments during construction, all in-water work would be conducted using BMPs that will be identified in the design specifications and in the remedial action work plans. In addition, all in-water work would be conducted and monitored in accordance with EPA's CWA Section 401 Water Quality Certification, which would specify allowable in-water work periods, water quality monitoring requirements and compliance criteria, and operational responses to any water quality exceedances. The contractor would be required to modify operations or employ other engineering measures (e.g., use different equipment or silt curtains) as needed to remain in compliance with water quality criteria.

Under Alternative 1, the sediment removal at the head of the slip would likely be accomplished by excavation, because the anticipated bottom elevation of the excavation would likely allow the work to be accomplished in-the-dry at low tides. It is anticipated that bank excavation and capping would be accomplished with shore-based equipment and constructed during periods of low tide, as practicable. Most capping in the slip would be completed with floating equipment, working at higher tides as needed to provide the required draft for the barges. Under-pier cap material would likely be placed with a conveyor or other methods to cast the material into place. Some areas above 0 feet MLLW may also be capped in-the-dry when the tides are out.

A specialty contractor would clean the Georgetown flume using specialized equipment such as high-powered vacuum equipment. To avoid project delays this action may be contracted separately and completed prior to the Slip 4 removal action.

Institutional Controls

Institutional controls would be required under Alternative 1 because some hazardous substances would remain on-site (contained beneath engineered caps) at levels that do not allow unlimited use and unrestricted exposure. Institutional controls would be employed as an additional measure to ensure the long-term protectiveness and integrity of the remedy, and would exist in perpetuity. The specific objectives of the institutional controls would be to:

- Prevent any uncontrolled excavation or construction that may compromise the cap integrity.
- Prevent any current or future land uses that could compromise the cap integrity.
- Require notification of the state and EPA prior to any development or redevelopment of the site, to ensure that the agencies concur that the development has been designed to avoid damage to the cap. If the cap must be disturbed as part of the activity, the notification would be required to include specific plans for appropriate management of the construction and restoration of the cap, as applicable. The specific plans must be approved by EPA prior to implementation.
- Ensure that these restrictions will run with the land.

Under Alternative 1, land use in the affected portion of Slip 4 would primarily be recreational navigation, sport fishing, and tribal fishing. Industrial land use would continue on adjacent upland parcels. Within the EAA boundaries, no commercial navigation would occur in support of Crowley's operations and no future dredging would occur in support of navigation. The proposed institutional control requirements for Alternative 1 have been developed with regard to these land uses. (Current land uses are further described in Section 2.1.7 and their relationship to the removal action scope is discussed in Section 3.1.3.) The proposed institutional control requirements would not preclude the Muckleshoot Tribe from exercising treaty-protected fishing activities in the area in the future.

The use of institutional controls is governed by both EPA guidance (EPA 2000, 2004, 2005c) and MTCA regulation (WAC 173-340-440). Proprietary Controls (i.e., land use restrictions) are the type of institutional controls that would be applied to the entire Slip 4 EAA. Land use restrictions would be placed on the property to prevent any uncontrolled excavation or construction that may compromise the cap integrity. Any future excavation would require appropriate plans for managing the construction and replacing the cap if the underlying contaminated material is not completely removed. The land use restrictions would require notice to and approval from EPA and Ecology for any future excavation. The land use restrictions would also allow access by EPA, Ecology, the City of Seattle, and King County for future long-term monitoring and maintenance activities. The need for any navigation restrictions (such as limiting heavy tug operations or

restricting use of heavy anchors) would be addressed in design. The land use restrictions would run with the land in the event of property transfer, and would be required for as long as hazardous substances remain on-site at levels that do not allow unlimited use and unrestricted exposure. The Institutional Control Implementation Plan (described below) would include specifics on these general requirements and provide all implementation specifics.

The land use restrictions would apply to all areas within the removal boundaries, including property owned by First South Properties and the City of Seattle. The portions of these properties outside of the removal boundaries would not be covered by land use restrictions. The legal mechanisms for implementation would differ for the parcels according to the ownership (private vs. government entity):

- In the case of private ownership (First South Properties and potentially Crowley Marine Services), the land use restrictions would be implemented through a restrictive covenant placed on the affected portion of their property, in accordance with WAC 173-340-440 (8)(a). The covenant would be executed by the property owner and recorded with the register of deeds for King County. This restrictive covenant would run with the land, and be binding on the owner's successors and assigns.
- In the case of parcels owned by the City of Seattle, the land use restrictions would be implemented through an alternative system that is equivalent to a restrictive covenant, in accordance with WAC 173-340-440 (8)(b), if approved by the agencies. The City would implement the alternative system as part of the Institutional Control Plan (described below). If the City of Seattle later transferred ownership in any portion of the property, it would file a restrictive covenant upon transfer.

Regardless of the specific implementation mechanisms described above, the land use restrictions would fulfill all of the performance requirements of WAC 173-340-440 (9). EPA may require additional information that will be provided in the Institutional Control Implementation Plan (ICIP).

Other regulatory programs would also address the capped contaminated sediment that could be potentially exposed by future projects that might be proposed within the capped area. Such projects may be associated with currently unplanned future development scenarios. Permitting requirements under Section 404 of the CWA and the Washington State Shoreline Management Act would address such scenarios and require appropriate design elements, such as (but not limited to) requirements for handling and disposal of contaminated sediments, restoration of the cap following dredging, or dredging to remove all sediments above the SQS. Similarly, these existing regulatory programs (along with Endangered Species Act requirements) would address any changes to habitat quality or quantity should such future projects be proposed. For example, a future project could

not eliminate or adversely affect aquatic habitat in the Slip 4 removal area without requiring mitigation under CWA Section 404.

If Alternative 1 is selected, the City and King County would prepare an ICIP during the design of the remedy. The ICIP would include an analysis and recommendations on institutional controls needed to ensure the long-term effectiveness of the removal action, including the objectives and goals for each institutional control; descriptions of the portions of the site where each institutional control applies; descriptions of how such controls would be implemented, monitored, and enforced, and by whom and under what enforcement mechanism; a timeframe for how long the institutional controls must remain in place; and, under what circumstances such controls could be removed or terminated. The ICIP would specifically describe the four categories of institutional controls (governmental, proprietary, enforcement, informational), and identify the institutional controls to be implemented under each category. When construction of the cleanup is completed, a report would be submitted to EPA and Ecology describing the progress towards implementation of the ICIP at that time. When all institutional controls are in place, an Institutional Control Implementation Report would be submitted to EPA and Ecology, documenting complete implementation of the ICIP, and including copies of all relevant paperwork (e.g., easements, filings with Records Offices). The ICIP and Institutional Control Implementation Report would be required under the Administrative Settlement Agreement and Order on Consent for Removal Action (Settlement Agreement) for the Slip 4 EAA.

Monitoring, Maintenance, and Reviews

A Long-term Monitoring and Reporting Plan (LTMRP) would be developed during the design that defines the specific monitoring activities and frequencies of monitoring events. The City would implement the requirements of this plan to ensure the long-term integrity and protectiveness of the remedy, and ensure that habitat benefits are not lost over the long term. Further, the plan will detail the process for contingency planning and response in the event that performance standards are not met. The need for any maintenance of capped areas would be determined based on the results of the long-term monitoring. Because this alternative would result in contaminants remaining onsite above levels that allow for unlimited use and unrestricted exposure, EPA would review the effectiveness of the remedy no less frequently than every five years.⁶

Summary of Construction Quantities

The estimated volumes of bank excavation, dredging, and capping associated with Alternatives 1 through 4 are summarized in Table 5-1. Note, however, that under the

⁶ EPA generally conducts their 5-year reviews on a site-wide basis, and thus the reviews for the LDW site (including Slip 4) may be on a different schedule than the Slip 4 monitoring events.

Dredged Material Management Program (DMMP), “dredged material” is broadly defined and can include some volume of material excavated from upland locations as long as this excavation has demonstrable ecological benefits at the dredging or disposal site (DMMP 2003). Consistent with this definition, for all alternatives, all material removed by both bank excavation and dredging may be considered to be dredged material. For the purposes of this EE/CA, the term “bank excavation” is used for bank material that would be excavated using upland equipment. EPA tracks media as “soil” or “sediment.” Approximately 70 percent of the bank excavation material is considered to be “sediment” and 30 percent is considered “soil.”

5.1.2 Evaluation of Alternative 1

An initial evaluation of Alternative 1 is provided below. Section 6 includes a more detailed comparative analysis of the four alternatives.

Effectiveness: Alternative 1 would be effective in removing and containing sediments with PCBs and other chemicals of interest within the Slip 4 removal area. Both removal and capping are proven technologies that have been successfully implemented in similar CERCLA sediment cleanup actions. Alternative 1 satisfies the RAO for the Slip 4 removal area by creating a post-construction surface that meets the SQS chemical criteria and providing effective long-term containment of remaining material. By meeting the cleanup standards, Alternative 1 would be protective of human health and the environment. Land use restrictions, long-term monitoring, and periodic reviews would ensure long term protection of human health and the environment.

Alternative 1 could be implemented in compliance with all ARARs. ARARs related to habitat [including CWA 404(b)(1) requirements and ESA requirements] are of particular relevance to the Slip 4 removal action, because Slip 4 is important aquatic habitat to several species including threatened Puget Sound chinook and Coastal/Puget Sound bull trout. These ARARs include:

- CWA 404(b)(1) evaluation guidelines include assessing the potential effects of the cleanup on physical and chemical characteristics, biological characteristics, and particular habitat types. Alternative 1 ranks favorably under the 404(b)(1) guidelines because:
 - The dredging and capping activities would create a small net gain in total aquatic habitat area.
 - There would be net gains in intertidal and shallow subtidal habitat areas relative to both existing and historically permitted conditions.
 - The cap materials would require comparatively little armoring.
 - The final surface sediment chemistry would be improved to meet Washington State SMS.

- ESA considers how the alternative would affect the habitat of federally threatened and/or endangered species and assess any short-term impacts during construction. The physical, chemical, biological, and habitat evaluations under the CWA 404(b)(1) analysis are also relevant to ESA. After a cleanup alternative is selected and during the design phase, the City would prepare a biological assessment. EPA would then consult with NOAA Fisheries and USFWS to determine compliance with ESA and ensure that appropriate conservation measures are incorporated into the design. The dredging and capping activities under Alternative 1 are not expected to jeopardize the continued existence of threatened and/or endangered species. The cap design would incorporate habitat enhancement features to improve habitat for threatened Puget Sound chinook and Coastal/Puget Sound bull trout, consistent with ESA goals. Specific effects of the alternatives on habitat acreages and elevations are further discussed in Section 6.

Alternative 1 would remove a total of approximately 8,100 cy of sediments and soils containing PCBs, and dispose of this material in a permitted upland landfill approved by EPA. Remaining impacted material would be reliably contained by capping. Alternative 1 does not include treatment to reduce the toxicity, mobility, or volume of contaminants.

Alternative 1 can be implemented in one construction season, and the RAO would be achieved upon completion of construction. The institutional controls could be fully implemented within approximately 1 year of construction completion. Engineering controls, BMPs, and other measures to ensure compliance with ARARs would control short-term risks during implementation. The potential for releases of material to the environment during construction would be minimal under Alternative 1, because a relatively small volume of contaminated material would be excavated, most excavation would occur in-the-dry, and all surrounding areas would subsequently be capped.

Alternative 1 relies primarily on containment through capping for reliable long-term physical and chemical isolation of the contaminated sediments. Under Alternative 1, near-surface material containing the highest concentrations of PCBs would remain in the head of the slip. This material can be effectively capped, and the potential for release of underlying sediments (e.g., from complete erosional failure of the cap) is small. However, the consequences of cap failure in this area may be greater than under the other alternatives. Alternative 1 would eliminate future navigational use of the EAA by heavy tugs, greatly reducing the potential for significant cap erosion by propeller wash. Caps would be designed for long-term function, and long-term performance would be verified through monitoring and periodic reviews. Land use restrictions would also contribute to the long-term integrity of the caps by reliably minimizing the potential for future uncontrolled activities that could disturb the caps.

Implementability: Based on the proven success of similar EPA Region 10 removal/capping projects, Alternative 1 can be reliably implemented using commonly available upland and marine construction equipment and materials. Excavated materials can be trucked or barged offsite and imported material brought onsite with conventional trucking or barge equipment. Most excavation under Alternative 1 could be completed when the tides are out, allowing easier control of the work and further limiting releases to the water column during excavation. For work on the banks and near the head of Slip 4, the contractor would schedule excavation and capping activities to take best advantage of low tides to accomplish work in-the-dry. The remainder of the work (including most capping) would likely be completed using floating equipment and conventional marine construction methods, working at higher tides as needed to provide the required draft for the barges.

Dredged or excavated materials would be loaded onto trucks onsite or loaded onto conventional barges and moved offsite. The material from barges would be offloaded to rail cars or trucks at a rehandling facility in the project vicinity.

Most of the work for Alternative 1 would be completed on submerged land that would be owned by the City. Portions of the Zone 3, 4, and 5 bank work (above +10 feet MLLW) would extend onto property owned by First South Properties. A small portion of the Zone 5 bank work may extend onto property owned by The Boeing Company. Land access and staging areas would be required on property owned by First South Properties. The City is coordinating with these property owners to arrange access and staging areas during the work, implement land-use restrictions for long-term protection of the capped area, and provide easements allowing access for future long-term monitoring activities.

Cost: The estimated removal action cost for Alternative 1 is detailed in Table 5-2. The total estimated costs include present-value operation and maintenance (O&M) costs estimated for 30 years, based on a 5 percent discount rate. Over the 30-year period, operation costs assume seven monitoring events, and maintenance costs assume one cap repair event. O&M costs were not projected beyond 30 years because their effect on net present value becomes diminishingly small.

5.2 ALTERNATIVE 2—CAPPING, TARGETED SEDIMENT REMOVAL, AND HABITAT ENHANCEMENT

5.2.1 Description of Alternative 2

Alternative 2 includes targeted removal of contaminated sediments, along with capping. The capping would affect Crowley Marine Service's navigation use of the inner berth, and hence the City would purchase a portion of Slip 4 from Crowley. Under Alternative 2, the extent of dredging/excavation would be based on achieving the following objectives:

- Accommodate outfall drainage

- Ensure no net loss of aquatic habitat
- Improve conditions of bank areas in preparation for capping (including improving slope stability, removing debris, and preparing a subgrade for cap placement)
- Remove near-surface material with the highest concentrations of contaminants
- Minimize changes to mudflat habitat at the head of the slip
- Consider improvements to intertidal habitat in locations where the City will own the bank and adjacent upland areas.

The dredging would be limited in scope to minimize impacts to adjacent structures and outfalls and avoid conversion of intertidal habitat to subtidal habitat. An area from the head of the slip to approximately Station 3+00 would be dredged a minimum of 3 feet. This dredging would be designed to accommodate a sediment cap that approximately reestablishes the existing contours in this area. This approach allows continued gravity flow of the existing outfall drainage systems while minimizing the potential for undermining outfall structures and the large dilapidated bulkhead in Zone 4. Piling, debris, and embankment material would be removed as described in Alternative 1. No dredging would occur south of Station 3+00.

An engineered sediment cap would be constructed over the entire Slip 4 removal area, including engineered slope caps on the Zone 3, 4, and 5 embankments. The cap would be engineered to withstand outfall scour and other erosive forces. Portions of the cap would be thickened and graded to expand and enhance shallow subtidal and intertidal habitat. Under Alternative 2, the City and King County have proposed certain improvements to intertidal habitat, and EPA understands that these improvements are considered relatively small increases in cost and effort relative to the overall alternative.

These elements are depicted conceptually in Figures 5-6 through 5-9 and described in further detail below.

Purchase of Land in the Slip 4 Removal Area

As described for Alternative 1, the capping actions under Alternative 2 would limit Crowley's historical and permitted use of their property. As compensation, if Alternative 2 was selected, the City would purchase (or otherwise acquire rights to) the land shown in Figure 5-1. If Alternative 2 was selected, the City would proceed with negotiations for a purchase and sale agreement with Crowley for this land. The negotiations may include a lot line adjustment in the under-pier area, so that no capped areas would remain in Crowley's ownership.

Piling and Debris Removal

Existing creosote-treated piling, failed bulkheads, and debris would be removed within the removal action area prior to dredging and capping, generally as described for Alternative 1. Under Alternative 2, additional debris embedded in the mud near the head of Slip 4 would be removed prior to the dredging. An estimated 500 tons of piling and debris would be removed and disposed of offsite.

Bank Excavation, Habitat Expansion, and Capping

Bank excavation and capping would occur generally as described for Alternative 1. Approximately 300 linear feet of the Zone 3 bank, 100 linear feet of the Zone 4 bank, and 140 linear feet of the Zone 5 bank would be excavated shoreward an average of 3 feet to a 2H:1V slope, removing impacted soil and sediment, creosote-treated timbers and piles, debris, and other material. The excavation would extend from the top of the bank down to approximately -3 feet MLLW in Zone 3 and approximately 0 feet MLLW in Zone 5.

In portions of Zone 2 and Zone 3 near the head of the slip where the City would have ownership of the adjacent uplands, the bank excavation would be extended landward to improve and expand intertidal habitat. The excavation in these areas (covering approximately 250 feet of shoreline) would create a shallower slope (approximately 3.5H:1V) and would create approximately 0.08 acres of new aquatic habitat from existing uplands. This intertidal habitat expansion is shown in plan view on Figure 5-6 and on the cross section at STA 1+00 on Figure 5-7. Overall, approximately 9,700 cy of bank material would be removed under Alternative 2.

The exposed surface following excavation would be sampled to document chemical concentrations beneath the cap; these data would be used in assessing long-term monitoring requirements. The excavated banks would then be capped using an engineered slope cap with a nominal thickness of approximately 3 feet. The slope cap would typically consist of layers of filter material (an engineered sandy gravel), quarry spalls or riprap (for erosion protection and slope stability), and a surface layer of sand and gravel (for improved habitat quality). Specific cap materials would be determined in the design.

The actual configuration of the bank excavation and capping would be established during design. Caps would be designed in general accordance with applicable EPA and USACE capping guidance (USEPA 1998). The caps would be designed for long-term static and seismic stability. Seismic stability is a concern primarily for the slope caps constructed on the banks. For the purposes of this EE/CA, maximum cap slopes (2H:1V) and cap materials are described that are consistent with regional embankment designs that meet with modeled and proven seismic stability. During design, appropriate seismic design criteria will be developed, and slopes and/or materials may be modified to ensure seismic

stability. Habitat design elements would be coordinated with the tribes and relevant federal and state agencies during the design process.

Under Alternative 2, excavation of the Zone 2 embankment is included only for the purpose of intertidal habitat expansion. The excavated portion of Zone 2 would be covered with slope cap materials for bank stabilization. Existing data from a single sample indicate that the Zone 2 embankment is below the SQS outside the removal boundary. Predesign investigations will further assess the quality of the Zone 2 embankment material. Should portions of this embankment significantly exceed the SQS, the design may include additional removal and/or capping in Zone 2.

Dredging/Excavation Within Slip 4

Approximately 4,300 cy of sediment would be removed from the head of the slip under Alternative 2. This sediment removal would be accomplished primarily or entirely by dredging (as opposed to excavation) because the anticipated bottom elevation of the cut (-4 feet MLLW or deeper) would not allow the work to be accomplished in-the-dry at low tides. Dredging would occur throughout the head of Slip 4 from Station 0+00 to approximately Station 2+50, and extend along the Zone 3 shoreline to approximately Station 3+00, as depicted on Figure 5-6. A minimum of 3 feet of material would be removed by the dredging.

This dredging would generally target the near-surface material with the highest concentrations of contaminants and would be designed to accommodate a sediment cap that approximately reestablishes the existing contours. This approach allows continued gravity flow of the existing outfall drainage systems while minimizing the potential for undermining outfall structures or destabilizing the Zone 4 bulkhead.

Consistent with these general objectives for targeted removal, the lateral extent and depth of dredging under Alternative 2 is configured based on the following information and engineering considerations:

- Near-surface material with the highest concentrations of contaminants occurs at the head of the slip in intertidal sediments (e.g., in the 0–2 foot interval at cores SC01 and SL4-6A; see Figures 5-6 through 5-9). This area exhibits PCB concentrations an order of magnitude greater than those throughout the rest of the removal area. The greatest benefits in terms of increased long-term effectiveness of capping are gained by removal of this near-surface material with comparatively high PCB concentrations.
- In the area targeted for dredging, the dredge cut would be designed to expose substantially cleaner material in order to improve the long-term effectiveness of capping. The depth of dredging in the mudflat area at the head of the slip would be designed to generally extend below the observed depth of contamination in the

existing cores, which is typically 2–4 feet below the mudline. An exception would be at core SL4-6A, where one CSL exceedance would remain at 6–8 feet below the mudline. The dredging would not be designed to remove all SQS or CSL exceedances because the area would be capped, but the exposed surface would be substantially cleaner than the material that is removed.

- Dredging would be avoided in areas where deep subsurface sediment contamination is overlain by relatively clean sediment. For example, SC-02 and SC-03 have deep deposits of contaminated material but the top 2 feet of material is below the CSL. This cleaner surface layer would enhance the long-term cap performance by providing an additional barrier to any contaminant transport.
- Dredging south of SC-02 would require 8–12 feet of removal and substantial amounts of backfill. The additional costs and short-term impacts of this deep dredging would be disproportionate to the very small gains in long-term protectiveness. For these reasons, SC-02 is the southern limit of dredging within the inner berth area under Alternative 2.
- The dredge cut extends to approximately STA 3+00 below the Zone 3 embankment, matching grades with the Zone 3 embankment excavation to improve constructability. In practical terms, the dredging area daylights near the existing -3 to -6 foot MLLW contour.
- Areas outside the dredge prism typically have surface (0–10 cm) sediment PCB concentrations below the CSL (see Figure 2-10), and, in many places, have surface deposits 2 feet or thicker that are below the CSL. As described above, these cleaner surface layers would enhance the long-term cap performance by providing an additional barrier to any contaminant transport.
- Removal of deeper sediments in areas outside the dredge prism would not reduce risk, because exposure occurs at the surface and there is no significant migration pathway to the surface.
- Areas outside the dredge prism have maximum subsurface PCB concentrations (at any depth) in the general range of 300–690 mg/kg OC, or roughly 5–15 mg/kg DW. These PCB concentrations are substantially lower than the concentrations targeted for dredging, have no significant migration pathway to the surface (where exposure may occur), are overlain by cleaner sediment deposits, and can be reliably capped to ensure long-term protectiveness of human and ecological receptors. Further, given the degree of analytical variability and sediment heterogeneity, it would be difficult to defensibly define any remaining lateral areas with statistically significant outlying “high” concentrations.

- Consistent with all of the above considerations, dredging or excavation in front of the Zone 4 bulkhead is avoided to minimize the potential for destabilizing the bulkhead. Also, dredging is avoided in areas that are currently below -10 feet MLWW. As a result, cap placement in these deeper areas will raise the elevations in these areas and increase the area of shallow subtidal habitat.

The specific dredge cuts would be refined during the design. Details for dredging and capping around the outfalls, including any necessary temporary stabilization measures to protect the outfall structures, would be developed in the design.

Georgetown Flume Actions

As described for Alternative 1, sediment accumulations within the lowest 370-foot segment of the Georgetown flume immediately upgradient from the outfall structure will be assessed during predesign investigations. Any significant accumulations would be removed either as part of this NTCRA or as a separate action by the City. Modifications to the outfall structure would be incorporated into the design if modifications are determined to be necessary to ensure proper function.

Sediment Capping Within Slip 4

Engineered sediment caps would be placed throughout the Slip 4 removal area to physically and chemically isolate any affected sediments not removed by dredging. The specific cap configurations would be determined in the design, in accordance with EPA and USACE guidance (USEPA 1998). The caps would be designed for long-term seismic stability. The overall capping plan is depicted on Figure 5-6.

The cap thicknesses and materials would be as described for Alternative 1, with minor design differences due to the additional dredging that would occur at the head of Slip 4. Under Alternative 2, the final cap surface in the dredged area (from Station 0+00 to approximately Station 2+50) would approximately reestablish the existing mudline. As with Alternative 1, outfall flows at the head of the slip would be directed into a swale in the cap, engineered with appropriate erosion protection. Under-pier cap material would be placed as described for Alternative 1.

As with Alternative 1, the cap thickness would be increased to up to 5 feet thick along the eastern portion of the slip, as generally depicted on Figures 5-6 and 5-8. The objectives of this thickening are to protect Native American shellfishing treaty rights and to enhance and expand intertidal and shallow subtidal habitat. The specific grading plan would be determined in design, in coordination with the Natural Resource Trustees.

Bank areas in Zones 3, 4, and 5 would be capped as previously described, and cap material would also be placed on the excavated Zone 2 embankment for slope stabilization. The total cap volume under Alternative 2 is approximately 27,000 cy.

Residuals Management

Dredging and bank excavation under Alternative 2 would be accomplished using BMPs to reduce the potential for resuspension and mobilization of contaminated sediments. However, during any dredging or excavation action, some disturbed, contaminated material often remains at the new surface—this material is referred to as “residuals.” Residuals can affect the dredged or excavated area as well as nearby surrounding areas. BMPs during dredging would reduce the generation of residuals. The following paragraphs discuss how any remaining residuals would be managed after the dredging and excavation.

Under this alternative, none of the dredged or excavated areas would be left uncapped, and the dredge/excavation cuts are not necessarily designed to expose a clean surface. Also, the dredging area is far removed from the southern boundary of the EAA, minimizing the possibility of fugitive dredge residuals affecting offsite areas. Therefore, any residuals would be permanently contained by the planned capping which would occur after dredging is complete. No additional contingencies or management actions (such as overdredging) are required following the dredging/excavation. However, post-excavation samples would be collected on the exposed surfaces of the excavated embankments to document the nature of the material beneath the cap. It is possible that the excavations would remove all contaminated material on portions of the embankments, in which case the final cap may require a lesser degree of long-term monitoring and maintenance.

Confirmation samples would also be collected on top of all final cap surfaces and in the area immediately south of the subtidal removal boundary to verify compliance with the cleanup standards. Because capping involves minimal disturbance of existing bottom sediments, there is little potential for contaminant transport to areas south of the subtidal removal boundary, and the need for residuals management actions in this area is unlikely. However, the design will include provisions for residuals management actions south of the subtidal removal boundary, if needed.

Material Handling, Transportation, and Disposal

Material handling, transportation, and disposal would be as described for Alternative 1.

Construction Approach

The design will include plans and specifications that are primarily performance-based, with some requirements for sequencing of the work. (General sequencing issues are discussed further in Section 6.2.) The contractor will be required to submit a remedial action work plan that details the proposed construction means, methods, and schedule. The contractor’s work plan will be reviewed and approved by the City’s Engineer and EPA.

To reduce resuspension and mobilization of contaminated sediments during construction, all in-water work would be conducted using BMPs that will be identified in the design specifications and in the remedial action work plans. In addition, all in-water work would be conducted and monitored in accordance with EPA's CWA Section 401 Water Quality Certification, which would specify allowable in-water work periods, water quality monitoring requirements and compliance criteria, and operational responses to any water quality exceedances. The contractor would be required to modify operations or employ other engineering measures (e.g., use different equipment or silt curtains) as needed to remain in compliance with water quality criteria.

Most dredging and capping would be completed with floating equipment, working at higher tides as needed to provide the required draft for the barges. Because the sediments to be removed from the head of the waterway would generally be removed to elevations of -4 feet MLLW or deeper, this removal would be accomplished by dredging. Under-pier cap material would likely be placed with a conveyor or other equipment to cast the material into place. It is anticipated that bank excavation and capping would be accomplished with shore-based equipment and constructed during periods of low tide, as practicable. Some areas at the head of the waterway with final grades above 0 feet MLLW may be capped in-the-dry when the tides are out.

Georgetown flume cleanout actions would be accomplished as described for Alternative 1.

Institutional Controls

Institutional controls would be implemented as described for Alternative 1.

Monitoring, Maintenance, and Reviews

Long-term monitoring, maintenance, and periodic reviews would be implemented as described for Alternative 1.

Summary of Construction Quantities

The estimated volumes of bank excavation, dredging, and capping associated with Alternatives 1 through 4 are summarized in Table 5-1.

5.2.2 Evaluation of Alternative 2

An initial evaluation of Alternative 2 is provided below. Section 6 includes a more detailed comparative analysis of the four alternatives.

Effectiveness: Alternative 2 would be effective in removing and containing sediments with PCBs and other chemicals of interest within the Slip 4 removal area. Both removal and capping are proven technologies that have been successfully implemented in similar

CERCLA sediment cleanup actions. Alternative 2 satisfies the RAOs for the Slip 4 removal area by creating a post-construction surface that meets the SQS chemical criteria, and providing effective long-term containment of remaining material. By meeting the cleanup standards, Alternative 2 would be protective of human health and the environment. Land use restrictions, long-term monitoring, and periodic reviews would ensure long-term protection of human health and the environment.

Alternative 2 could be implemented in compliance with all ARARs. ARARs related to habitat [including CWA 404(b)(1) requirements and ESA requirements] are of particular relevance to the Slip 4 removal action, because Slip 4 is important aquatic habitat to several species including threatened Puget Sound chinook and Coastal/Puget Sound bull trout. These ARARs include:

- CWA 404(b)(1) evaluation guidelines include assessing the potential effects of the cleanup on physical and chemical characteristics, biological characteristics, and particular habitat types. Alternative 2 ranks favorably under the 404(b)(1) guidelines because:
 - The dredging and capping activities would create a small net gain in total aquatic habitat area.
 - There would be net gains in intertidal and shallow subtidal habitat areas relative to both existing and historically permitted conditions.
 - The cap materials would require comparatively little armoring.
 - The final surface sediment chemistry would be improved to meet Washington State SMS.
- Compliance with ESA would be evaluated as described for Alternative 1. The dredging and capping activities under Alternative 2 are not expected to jeopardize the continued existence of threatened and/or endangered species. The cap design would incorporate habitat enhancement features to improve habitat for threatened Puget Sound chinook and Coastal/Puget Sound bull trout, consistent with ESA goals. Specific effects of the alternatives on habitat acreages and elevations are discussed further in Section 6.

Alternative 2 would remove a total of approximately 14,000 cy of sediments and soils containing PCBs from the aquatic environment, and dispose of this material in a permitted upland landfill approved by EPA. Remaining impacted material would be reliably contained by capping. Alternative 2 does not include treatment to reduce the toxicity, mobility, or volume of contaminants.

Alternative 2 can be implemented in one construction season, and the RAO would be achieved upon completion of construction. The institutional controls could be fully implemented within approximately 1 year of construction completion. Engineering controls, BMPs, and other measures to ensure compliance with ARARs would control

short-term risks during implementation. The potential for releases of material to the environment during construction would be minimal under Alternative 2, because roughly half of the excavation would likely occur in-the-dry, and all surrounding areas would subsequently be capped.

Alternative 2 relies on containment through capping for reliable long-term physical and chemical isolation of remaining contaminated sediments. Under Alternative 2, sediments containing the highest concentrations of PCBs would be removed from the head of the slip before capping. Also, the targeted removal under Alternative 2 would eliminate areas where comparatively high PCB concentrations immediately underlie the cap. Remaining material that exceeds the CSL would generally be contained under existing layers of cleaner sediments, which in turn would be contained by engineered cap materials. These cleaner sediment deposits beneath the cap would enhance the long-term cap performance by providing an additional barrier to any contaminant transport. Alternative 2 would also eliminate future navigational use of the EAA by heavy tugs, greatly reducing the potential for significant cap erosion by propeller wash. Caps would be designed for long-term function, and long-term performance would be verified through monitoring and periodic reviews. Land use restrictions would also contribute to the long-term integrity of the caps by reliably minimizing the potential for future uncontrolled activities that could disturb the caps.

Implementability: Based on the proven success of similar EPA Region 10 removal/capping projects, Alternative 2 can be reliably implemented using commonly available upland and marine construction equipment and materials. Excavated materials can readily be trucked or barged offsite and imported material brought onsite with conventional trucking or barge equipment. Roughly half of the excavation under Alternative 2 could be completed when the tides are out, allowing easier control of the work and further limiting releases to the water column during excavation. For the bank work, the contractor would schedule excavation and capping activities to take best advantage of low tides to accomplish work in-the-dry. The remainder of the work (including most capping) would be completed using floating equipment and conventional marine construction methods, working at higher tides as needed to provide the required draft for the barges.

Dredged or excavated materials would be either loaded onto trucks onsite or loaded onto conventional barges and moved offsite. The material from barges would be offloaded to either rail cars or trucks at a rehandling facility in the project vicinity.

Most of the work for Alternative 2 would be completed on submerged land that would be owned by the City. Portions of the Zone 3, 4, and 5 bank work (above +10 feet MLLW) would extend onto property owned by First South Properties. A small portion of the Zone 5 bank work may extend onto property owned by The Boeing Company. Land access and staging areas would be required on property owned by First South Properties.

The City is coordinating with these property owners to arrange access and staging areas during the work, implement land-use restrictions for long-term protection of the capped area, and provide easements allowing access for future long-term monitoring and maintenance activities.

Cost: The estimated removal action cost for Alternative 2 is detailed in Table 5-3. The total estimated costs include present-value O&M costs estimated for 30 years, based on a 5 percent discount rate. Over the 30-year period, operation costs assume seven monitoring events, and maintenance costs assume one cap repair event. O&M costs were not projected beyond 30 years because their effect on net present value becomes diminishingly small.

5.3 ALTERNATIVE 3—INNER BERTH SEDIMENT REMOVAL AND CAPPING

5.3.1 Description of Alternative 3

Alternative 3 includes removal of contaminated sediments in the inner berth and at the head of Slip 4, along with capping outside of the inner berth. Under Alternative 3, the extent of dredging/excavation would be based on achieving the following objectives:

- Accommodate outfall drainage
- Ensure no net loss of aquatic habitat
- Improve conditions of bank areas in preparation for capping (including improving slope stability, removing debris, and preparing a subgrade for cap placement)
- Remove near-surface material with the highest concentrations of contaminants
- Minimize changes to mudflat habitat at the head of the slip
- Remove contaminated material in the inner berth, to reestablish historically permitted navigation depths
- Attain a clean dredged surface in the inner berth.

The dredging would be limited in scope to minimize impacts to adjacent structures and outfalls. Contaminated sediments in the inner berth would be dredged to an elevation of -16 feet MLLW or deeper (dredge depths would be determined in design). Additional dredging, enhanced natural recovery, or capping may be required in the inner berth to leave a clean surface (concentrations below the SQS). The final surface within the inner berth would be no higher than -15 feet MLLW.

Because Alternative 3 would restore Crowley's historical navigation use of the inner berth, Crowley would retain ownership of its portion of Slip 4.

An area from the head of the slip to approximately Station 3+00 would also be dredged a minimum of 3 feet. Piling, debris, and embankment material from Zones 3, 4, and 5 would be removed as generally described in Alternative 1. However, because upland property ownership would remain unchanged, Alternative 3 does not include additional bank excavation for habitat expansion in Zones 2 and 3.

An engineered sediment cap would be constructed in the portion of the removal area outside of the inner berth, including engineered slope caps on the Zone 3, 4, and 5 embankments. The cap would be engineered to withstand outfall scour and other erosive forces.

These elements are depicted conceptually in Figures 5-10 through 5-13 and described in further detail below.

Piling and Debris Removal

Existing creosote-treated piling, failed bulkheads, and debris would be removed within the removal action area prior to dredging and capping, generally as described for Alternative 1. Under Alternative 3, additional debris embedded in the mud near the head of Slip 4 and in the inner berth would be removed prior to the dredging. An estimated 600 tons of piling and debris would be removed and disposed of offsite.

Bank Excavation and Capping

Bank excavation and capping would occur generally as described for Alternatives 1 and 2. However, because upland property ownership would remain unchanged, Alternative 3 does not include additional bank excavation for habitat expansion in Zones 2 and 3.

Approximately 300 linear feet of the Zone 3 bank, 100 linear feet of the Zone 4 bank, and 140 linear feet of the Zone 5 bank would be excavated shoreward an average of 3 feet to a 2H:1V slope, removing impacted soil and sediment, creosote-treated timbers and piles, debris, and other material. The excavation would extend from the top of the bank down to approximately -3 feet MLLW in Zone 3 and approximately 0 feet MLLW in Zone 5. Overall, approximately 3,200 cy of bank material would be removed under Alternative 3.

The exposed surface following excavation would be sampled to document chemical concentrations beneath the cap; these data would be used in assessing long-term monitoring requirements. The excavated banks would then be capped using an engineered slope cap with a nominal thickness of approximately 3 feet. The slope cap would typically consist of layers of filter material (an engineered sandy gravel), quarry spalls or riprap (for erosion protection and slope stability), and a surface layer of sand and gravel (for improved habitat quality).

The actual configuration of the bank excavation and capping would be established during design. Caps would be designed in general accordance with applicable EPA and USACE capping guidance (USEPA 1998). The caps would be designed for long-term static and seismic stability. Seismic stability is a concern primarily for the slope caps constructed on the banks. For the purposes of this EE/CA, maximum cap slopes (2H:1V) and cap materials are described that are consistent with regional embankment designs that meet with modeled and proven seismic stability. During design appropriate seismic design criteria will be developed, and slopes and/or materials may be modified to ensure seismic stability. Habitat design elements would be coordinated with the tribes and relevant federal and state agencies during the design process. The bank excavation and capping would be configured to avoid any net loss of aquatic habitat acreage.

Under Alternative 3, no excavation or capping of the Zone 2 embankment is currently anticipated. Predesign investigations will further assess the quality of the Zone 2 embankment material. Should portions of this embankment significantly exceed the SQS, the design may include additional removal and/or capping in Zone 2.

Dredging/Excavation Within Slip 4

Approximately 24,000 cy of sediment would be dredged under Alternative 3. Dredging would occur in the inner berth area and from the head of Slip 4 to approximately Station 3+00, as depicted on Figure 5-10.

Contaminated sediments in the inner berth would be dredged, which would restore navigable capacity to historically permitted conditions (i.e., no higher than -15 feet MLLW within the permitted footprint). Analysis of cores within or in near the inner berth generally indicate PCBs at concentrations above the SQS extend to -15 feet MLLW or deeper. For the purposes of this EE/CA, the conceptual dredging design in the inner berth is based on limited existing core data and historical dredging documentation. Additional predesign characterization would be required under this alternative to refine the dredging plan and prepare appropriate contingency measures should the dredging in the inner berth fail to reach clean material.

The inner berth would be dredged to specified elevation(s) that would be determined in design. The design dredge elevations would likely be no higher than -16 feet MLLW, which is one foot deeper than the deepest historical dredge depth and the approximate elevation at which uncontaminated native sediments may be expected. One core (SC-03) has been completed to the bottom of the inner berth dredge prism. This core indicated SQS exceedances to a depth of -18.5 feet MLLW. This may reflect considerable variability in the recent/native sediment interface associated with variability in the actual historical dredging elevations. Dredge elevations and slopes would be determined in design, following additional coring that would be accomplished in predesign investigations. Sideslopes of the dredge prism are assumed to be excavated at slopes of 2H:1V. If flatter

slopes are required to reduce the potential for sloughing, then the dredge quantities may increase somewhat. Under-pier sediments would be removed using mechanical equipment to the maximum extent practicable. Some residual sediments would remain atop the riprap under the pier. Cap material would be placed over these sediments as described below.

Outside of the inner berth, dredging would occur in the head of Slip 4 from Station 0+00 to approximately Station 3+00. As with Alternative 2, a minimum of 3 feet of material would be removed by dredging. This dredging would remove near-surface material with the highest concentrations of contaminants and create room for a sediment cap that approximately reestablishes the existing contours. This approach allows continued gravity flow of the existing outfall drainage systems while minimizing the potential for undermining outfall structures or destabilizing the dilapidated bulkhead in Zone 4.

The specific dredge cuts would be refined during the design. Details for dredging and capping around the outfalls, including any necessary temporary stabilization measures to protect the outfall structures, would be developed in the design.

Under Alternative 3, dredging extends to the southern boundary of the EAA, and fugitive dredge residuals could affect areas south of the EAA. In addition to specifying common dredging BMPs, the use of engineering controls such as silt curtains would be evaluated in design to determine if they are likely to be feasible and cost-effective in minimizing offsite transport of suspended contaminated sediments generated by the dredging.

Georgetown Flume Actions

As described for Alternative 1, sediment accumulations within the lowest 370-foot segment of the Georgetown flume immediately upgradient from the outfall structure will be assessed during predesign investigations. Any significant accumulations would be removed either as part of this NTCRA or as a separate action by the City. Modifications to the outfall structure would be incorporated into the design if modifications are determined to be necessary to ensure proper function.

Sediment Capping Within Slip 4

Engineered sediment caps would be placed in areas outside the inner berth to physically and chemically isolate any affected sediments not removed by dredging. The specific cap configurations would be determined in the design, in accordance with EPA and USACE guidance (USEPA 1998). The caps would be designed for long-term seismic stability. The overall capping plan is depicted on Figure 5-10. Under Alternative 3, the inner berth would be returned to active navigation uses, and therefore the surrounding caps would require additional armoring to resist increased erosive forces from propeller wash.

At the head of Slip 4, from Station 0+00 to Station 1+50, the cap would be appropriately graded and designed to resist erosive forces from outfall flows and propeller wash and allow proper drainage. The cap would typically consist of layers of filter material, quarry spalls, or riprap armoring, and a surface layer of sand and gravel.

Outside the inner berth, from Station 1+50 to approximately Station 7+00 (the removal area boundary), the cap would likely have a similar armored configuration, with layers of filter material, quarry spalls, or riprap armoring, and a surface layer of sand and gravel.

The cap would be designed with armoring as needed to resist erosive forces from propeller wash associated with navigation in the inner berth. The cap thickness in this area would be approximately 3 feet (in contrast to the thicker cap that would be placed under Alternatives 1 or 2). The cap armoring would limit any cap disturbance caused by shellfishing activities. Furthermore, the adjacent slip deepening, armoring requirements, and slope stability issues limit opportunities for habitat enhancement in this area. The specific grading plan and cap materials would be determined in design, in coordination with the Natural Resource Trustees.

Armoring would be extended down the sideslopes of the inner berth dredge prism, as illustrated in Figures 5-11 to 5-13. This armoring would be required to resist erosive forces from propeller wash and maintain the stability of the capped areas surrounding the inner berth.

Cap material would be placed under the pier to physically stabilize and isolate any residual sediments remaining atop the riprap under the pier. The under-pier cap material would be designed for erosion resistance and would likely be a blend of filter material and larger rock.

Bank areas in Zone 3, 4, and 5 would be capped as previously described. The total cap volume under Alternative 3 is approximately 17,000 cy.

Residuals Management

Dredging and bank excavation would be accomplished using BMPs to reduce the potential for resuspension and mobilization of contaminated sediments. However, during any dredging or excavation action, some disturbed, contaminated material often remains at the new surface—this material is referred to as “residuals.” Residuals can affect the dredged or excavated area as well as nearby surrounding areas. BMPs during dredging would reduce the generation of residuals. The following paragraphs discuss how any remaining residuals would be managed after the dredging.

Under Alternative 3, dredge residuals are a concern both in the inner berth area and in the area south of the removal boundary. The inner berth would be initially dredged to -16 feet MLLW or deeper, as determined by the results of predesign coring in the inner

berth. Confirmation samples would be collected to determine whether the new sediment surface meets the post-construction cleanup standards. Should the cleanup standards be exceeded, residuals would be managed using one or more of the following contingency actions:

- Additional dredging
- Placement of a thin (approximately 6-inch) layer of sandy material for enhanced natural recovery
- Placement of a thick engineered cap (after additional dredging)
- MNR.

The design would include limitations on any additional dredging as required to maintain slope and structural stability. Following any required contingency actions, the final surface in the inner berth would be no higher than -15 feet MLLW. The final surface in the inner berth would either have chemical concentrations below the cleanup standards or would be monitored for natural recovery if MNR is determined to be an appropriate contingency action. The design may include an evaluation of chemical concentrations that may be suitable for MNR. If surface concentrations exceeded these levels, then additional active management of the residuals would be required (e.g., additional dredging).

Confirmation samples would also be collected on all final cap surfaces and in the area immediately south of the removal boundary to verify compliance with the cleanup standards. For cost-estimating purposes, it is assumed that contingency actions would include 1–2 feet of additional dredging in the inner berth area and placement of up to 2,500 cy of additional cap material for enhanced natural recovery. The enhanced natural recovery material is assumed to be required in both the inner berth area and an area extending approximately 100 feet south of the removal boundary. It is noted that the feasibility of using enhanced natural recovery south of the removal area would require further evaluation in design. A portion of this area is the permitted dredge prism of Crowley's middle berth, and placement of material for enhanced natural recovery may interfere with navigation or increase future maintenance dredging costs.

Material Handling, Transportation, and Disposal

Material handling, transportation, and disposal would be as described for Alternative 1.

Construction Approach

The design will include plans and specifications that are primarily performance-based, with some requirements for sequencing of the work. (General sequencing issues are discussed further in Section 6.2.) The contractor will be required to submit a remedial

action work plan that details the proposed construction means, methods, and schedule. The contractor's work plan will be reviewed and approved by the City's Engineer and EPA.

As described for Alternative 2, all in-water work would be conducted using BMPs that will be identified in the design specifications and in the remedial action work plans. In addition, all in-water work would be conducted and monitored in accordance with EPA's CWA Section 401 Water Quality Certification.

Most dredging and capping would be completed with floating equipment, working at higher tides as needed to provide the required draft for the barges. Because the sediments to be removed from the head of the waterway would generally be excavated to elevations of -4 feet MLLW or deeper, this removal would be accomplished by dredging. It is anticipated that bank excavation and capping would be accomplished with shore-based equipment and constructed during periods of low tide, as practicable. Some areas at the head of the waterway with final grades above 0 feet MLLW may be capped in-the-dry when the tides are out.

Under-pier sediments would be removed by first dredging to the design depth at the face of the pier and allowing the under-pier sediments to slough into the excavation. A barge-mounted excavator may be used to move the majority of remaining under-pier sediments out from under the pier. The area in front of the pier face would then be re-dredged. Under-pier cap material would be placed mechanically or with a conveyor. Under Alternative 3, the fender piling at the face of the pier would likely need to be removed and replaced to gain access for these actions.

Georgetown flume cleanout actions would be accomplished as described for Alternative 1.

Institutional Controls

Institutional controls would generally be as described for Alternative 1. However, under Alternative 3, the overall land use in the affected portion of Slip 4 would primarily be industrial navigation, along with recreational navigation, sport fishing, and tribal fishing. Industrial land use would continue on adjacent upland parcels. Within the inner berth portion of the EAA boundaries, commercial navigation would occur in support of Crowley's operations. Periodic maintenance dredging of the inner berth would likely occur in the future to maintain navigable depths. The proposed institutional control requirements under Alternative 3 have been developed with regard to these land uses.

Under Alternative 3, all property in the Slip 4 EAA would remain in private ownership (by Crowley and First South Properties). Therefore the land use restrictions would be implemented through restrictive covenants placed on the affected portion of their properties, in accordance with WAC 173-340-440 (8)(a). The covenants would be executed by the property owners and recorded with the register of deeds for King County. This

restrictive covenants would run with the land, and be binding on the owners' successors and assigns.

In addition to the requirements described for Alternative 1, future maintenance dredging that may be required in the inner berth would require specific controls to minimize the potential for cap damage and maximize long-term reliability of the cap. These specific requirements would be incorporated into the restrictive covenants. In addition, permitting requirements under Section 404 of the CWA and the Washington State Shoreline Management Act would regulate the maintenance dredging and require appropriate design elements, such as (but not limited to) requirements for handling and disposal of contaminated sediments, restoration of the cap following dredging, or dredging to remove all sediments above the SQS.

Monitoring, Maintenance, and Reviews

Long-term monitoring, maintenance, and periodic reviews would be implemented as described for Alternative 1.

Summary of Construction Quantities

The estimated volumes of bank excavation, dredging, and capping associated with Alternatives 1 through 4 are summarized in Table 5-1.

5.3.2 Evaluation of Alternative 3

An initial evaluation of Alternative 3 is provided below. Section 6 includes a more detailed comparative analysis of the four alternatives.

Effectiveness: Alternative 3 would be effective in removing and containing sediments with PCBs and other chemicals of interest within the Slip 4 removal area. Both removal and capping are proven technologies that have been successfully implemented in similar CERCLA sediment cleanup actions. Alternative 3 satisfies the RAO for the Slip 4 removal area by creating a post-construction surface that meets the SQS chemical criteria and providing effective long-term containment of remaining material. By meeting the cleanup standards, Alternative 3 would also be protective of human health and the environment. Land use restrictions, long-term monitoring, and periodic reviews would ensure long term protection of human health and the environment.

Alternative 3 could be implemented in compliance with all ARARs. ARARs related to habitat [including CWA 404(b)(1) requirements and ESA requirements] are of particular relevance to the Slip 4 removal action, because Slip 4 is important aquatic habitat to several species including threatened Puget Sound chinook and Coastal/Puget Sound bull trout. These ARARs include:

- CWA 404(b)(1) evaluation guidelines include assessing the potential effects of the cleanup on physical and chemical characteristics, biological characteristics, and particular habitat types. Alternative 3 is acceptable under the 404(b)(1) guidelines, with the following considerations:
 - The dredging and capping activities would create no net loss of aquatic habitat.
 - The final surface sediment chemistry would be improved to meet Washington State SMS.
 - Dredging of the inner berth would decrease lower intertidal and shallow subtitle habitat acreage relative to existing conditions. The dredging would approximately restore historically permitted conditions.
 - The cap materials would require significant armoring.
- Compliance with ESA would be evaluated as described for Alternative 1. The dredging and capping activities under Alternative 3 may have adverse impacts to habitat, but are not expected to jeopardize the continued existence of threatened and/or endangered species. Where possible, the cap design would incorporate habitat enhancement features to improve habitat for threatened Puget Sound chinook and Coastal/Puget Sound bull trout, consistent with ESA goals. Specific effects of the alternatives on habitat acreages and elevations are further discussed in Section 6.

Alternative 3 would remove a total of approximately 27,000 cy of sediments and soils containing PCBs, and dispose of this material in a permitted upland landfill approved by EPA. Remaining impacted material would be reliably contained by capping. Alternative 3 does not include treatment to reduce the toxicity, mobility, or volume of contaminants.

Alternative 3 can likely be implemented in one construction season, although it is possible that an extension to the allowable in-water work period may be needed. The RAO would be achieved upon completion of construction. The institutional controls could be fully implemented within approximately 1 year of construction completion. Engineering controls, BMPs, and other measures to ensure compliance with ARARs would control short-term risks during implementation. Under Alternative 3, dredging would occur up to the southern removal area boundary, hence creating some potential for dredging residuals to affect a limited area south of the removal area boundary. Dredging residuals in the inner berth may exceed the SQS even after several dredging passes. Confirmation sampling and contingency actions would be employed as needed to address residuals.

Under Alternative 3, sediments containing the highest concentrations of PCBs would be removed from the head of the slip, and most or all sediments exceeding the SQS would be removed from the inner berth area. Alternative 3 relies on containment through capping for reliable long-term physical and chemical isolation of contaminated sediments that

would remain outside the inner berth area. Caps would be designed for long-term function, and long-term performance would be verified through monitoring and periodic reviews. Land use restrictions would also contribute to the long-term integrity of the caps by reliably minimizing the potential for future uncontrolled activities that could disturb the caps.

Under Alternative 3, caps surrounding the inner berth may be subject to significant erosive forces from propeller wash. Although caps would be designed to resist these erosive forces, some additional long-term cap monitoring and/or maintenance may be required. Furthermore, future maintenance dredging that may be required in the inner berth would require specific controls to minimize the potential for cap damage and maximize long-term reliability.

Implementability: Based on the proven success of similar EPA Region 10 removal/capping projects, Alternative 3 can be reliably implemented using commonly available upland and marine construction equipment and materials. Excavated materials can readily be trucked or barged offsite and imported material brought onsite with conventional trucking or barge equipment. A small portion of the excavation under Alternative 3 could be completed when the tides are out, allowing easier control of the work and further limiting releases to the water column during excavation. For the bank work, the contractor would schedule excavation and capping activities to take best advantage of low tides to accomplish work in-the-dry. The remainder of the work (including most dredging and capping) would be completed using floating equipment and conventional marine construction methods, working at higher tides as needed to provide the required draft for the barges.

Dredged or excavated materials would be either loaded onto trucks onsite or loaded onto conventional barges and moved offsite. The material from barges would be offloaded to either rail cars or trucks at a rehandling facility in the project vicinity.

While Alternative 3 can be reliably implemented, actions in the inner berth area would require special consideration of design, monitoring, and construction elements:

- Attaining SQS in the inner berth will require specific construction sequencing approaches and may result in contractor downtime. Two or more dredging passes would be required to attain a clean surface at the base of the dredge prism in the inner berth area. Sequencing the dredging relative to actions in adjacent areas is critical, and additional contingency measures, such as overdredging and enhanced natural recovery, may be required in the inner berth area. Similar contingency measures could be required in the area south of the removal boundary. Sequencing requirements and time required for confirmation sampling and analyses may result in downtime.

- Removal of under-pier sediments and placement of under-pier cap material may pose construction difficulties. Removal and replacement of fender piles will likely be required to improve access. A barge-mounted excavator would likely be used to move most under-pier sediments, as practicable. The same equipment or a conveyor would likely be used to place under-pier cap material. Due to limited overhead clearance, specific equipment selection and timing of the work for lower tides would be critical.

Most of the work for Alternative 3 would be completed on submerged land owned by Crowley Marine Services. Portions of the Zone 3, 4, and 5 bank work (above +10 feet MLLW) would extend onto property owned by First South Properties. A small portion of the Zone 5 bank work may extend onto property owned by The Boeing Company. Land access and staging areas would be required on property owned by First South Properties. The City is coordinating with these property owners to arrange access and staging areas during the work, implement land-use restrictions for long-term protection of the capped area, and provide easements allowing access for future long-term monitoring activities.

Cost: The estimated removal action cost for Alternative 3 is detailed in Table 5-4. The total estimated costs include present-value O&M costs estimated for 30 years, based on a 5 percent discount rate. Over the 30-year period, operation costs assume seven monitoring events, and maintenance costs assume four cap repair events. O&M costs were not projected beyond 30 years because their effect on net present value becomes diminishingly small.

5.4 ALTERNATIVE 4—MAXIMUM REASONABLE SEDIMENT REMOVAL

5.4.1 Description of Alternative 4

Alternative 4 includes removal of the majority of contaminated sediments throughout the Slip 4 EAA. Under Alternative 4, the extent of dredging/excavation would be based on achieving the following overall objective:

- Remove all materials exceeding the SQS where reasonably feasible, while minimizing impacts to adjacent structures and outfalls.

The excavation/dredging required to achieve this overall objective would also fulfill the following objectives:

- Accommodate outfall drainage
- Ensure no net loss of aquatic habitat

- Improve conditions of bank areas in preparation for capping (including improving slope stability, removing debris, and preparing a subgrade for cap placement)
- Remove near-surface material with the highest concentrations of contaminants
- Minimize changes to mudflat habitat at the head of the slip
- Remove contaminated material in the inner berth, to reestablish historically permitted navigation depths throughout the inner berth
- Attain a clean dredged surface in the inner berth.

Contaminated sediments in the inner berth would be dredged to an elevation of -16 feet MLLW or deeper (dredge depths would be determined in design). Additional dredging, enhanced natural recovery, or capping may be required in the inner berth to leave a clean surface (concentrations below the SQS). The final surface within the inner berth would be no higher than -15 feet MLLW.

Because Alternative 4 would restore Crowley's historical navigation use of the inner berth, Crowley would retain ownership of its portion of Slip 4.

Outside the inner berth, the remainder of the Slip 4 EAA would be dredged to elevations where clean sediments are expected to be encountered. The depth of dredging outside the inner berth would range from approximately 4 to 10 feet (dredge depths would be determined in design). The dredging would be limited in scope to minimize the potential for destabilizing adjacent slopes, structures, and outfalls. Piling, debris, and embankment material from Zones 3, 4, and 5 would be removed as generally described in Alternative 1. However, because upland property ownership would remain unchanged, Alternative 4 does not include additional bank excavation for habitat expansion in Zones 2 and 3.

Backfill material would be placed in the dredged areas outside of the inner berth, and engineered slope caps would be placed on the Zone 3, 4, and 5 embankments. The backfill and caps would be engineered to withstand outfall scour and other erosive forces.

These elements are depicted conceptually in Figures 5-14 through 5-17 and described in further detail below.

Piling and Debris Removal

Existing creosote-treated piling, failed bulkheads, and debris would be removed within the removal action area prior to dredging and capping, as described for Alternative 3. An estimated 600 tons of piling and debris would be removed and disposed of offsite.

Bank Excavation and Capping

Bank excavation and capping would occur generally as described for Alternative 3. However, in some locations the bank excavation would extend to lower elevations in the slip to match the deeper dredging elevations under Alternative 4. Overall, approximately 4,300 cy of bank material would be removed under Alternative 4.

As described for Alternative 3, the caps would be designed in general accordance with applicable EPA and USACE capping guidance (USEPA 1998), and the caps would be designed for long-term static and seismic stability. Habitat design elements would be coordinated with the tribes and relevant federal and state agencies during the design process. The bank excavation and capping would be configured to avoid any net loss of aquatic habitat acreage.

Dredging/Excavation Within Slip 4

Approximately 36,000 cy of sediment would be dredged under Alternative 4. Dredging would occur throughout the Slip 4 EAA as depicted on Figures 5-14 through 5-17. In all areas, the extent and depth of dredging would be based on the goal of removing all material exceeding the SQS, as limited by slope and structural stability considerations.

Contaminated sediments in the inner berth would be dredged to an elevation of -16 feet MLLW or deeper, as described for Alternative 3.

Outside of the inner berth, dredging would occur to specified elevation(s) that would be determined in design, following additional coring that would be accomplished in predesign investigations. Approximately 4 to 10 feet of material would be removed by the dredging (based on existing coring information). Sideslopes of the dredge prism would be excavated at slopes of 2H:1V or shallower to reduce the potential for destabilizing adjacent slopes, structures, and outfalls. Similarly, in some areas the dredging would need to be offset from structures to maintain stability. For example, the dredging would need to be offset from the remaining Zone 4 bulkhead to prevent the bulkhead from failing, as depicted on the cross section at Station 4+00 on Figure 5-16. This dredging would remove most of the contaminated sediments from the EAA; however, the dredging/excavation limitations discussed above would necessitate some contaminated sediments remaining in place around the perimeter of the Slip, including:

- Under the Crowley pier
- At the toe of the bank in Zones 2, 3, and 4
- In embankment soils in Zones 3, 4, and 5.

The specific dredge cuts would be refined during the design. Details for dredging and capping around the outfalls, including any necessary temporary stabilization measures to protect the outfall structures, would be developed in the design.

Under Alternative 4, dredging extends to the southern boundary of the EAA, and fugitive dredge residuals could affect areas south of the EAA. In addition to specifying common dredging BMPs, the use of engineering controls such as silt curtains would be evaluated in design to determine if they are likely to be feasible and cost-effective in minimizing offsite transport of suspended contaminated sediments generated by the dredging.

Georgetown Flume Actions

As described for Alternative 1, sediment accumulations within the lowest 370-foot segment of the Georgetown flume immediately upgradient from the outfall structure will be assessed during predesign investigations. Any significant accumulations would be removed either as part of this NTCRA or as a separate action by the City. Modifications to the outfall structure would be incorporated into the design if modifications are determined to be necessary to ensure proper function.

Backfilling/Capping Within Slip 4

Backfill material would be placed in areas outside the inner berth to minimize habitat disturbances by the deepening. In areas where dredging could not remove all contaminated materials, the backfill would function as a cap. The backfill would be designed to physically and chemically isolate any affected sediments not removed by dredging. The specific backfill/cap configurations would be determined in the design, in accordance with EPA and USACE guidance (USEPA 1998). Backfilled and capped areas would be designed for long-term static and seismic stability. The overall backfill/capping plan is depicted on Figure 5-14.

Under Alternative 4, the inner berth would be returned to active navigation uses. The surrounding backfill and caps would require armoring to resist erosive forces from propeller wash associated with navigation in the inner berth as well as outfall flows. The backfill/cap would typically consist of layers of filter material, quarry spalls, or riprap armoring, and a surface layer of sand and gravel.

The backfill/cap would be placed to approximately reestablish the existing mudline outside of the inner berth. As with Alternative 3, the adjacent slip deepening, armoring requirements, and slope stability issues limit opportunities for habitat enhancement. The specific grading plan and cap materials would be determined in design, in coordination with the Natural Resource Trustees.

Cap material would be placed under the pier to physically stabilize and isolate any residual sediments remaining atop the riprap under the pier. The under-pier cap material

would be designed for erosion resistance and would likely be a blend of filter material and larger rock.

Bank areas in Zone 3, 4, and 5 would be capped as described for Alternative 3. The total backfill/cap volume under Alternative 4 is approximately 26,000 cy.

Residuals Management

Dredging and bank excavation would be accomplished using BMPs to reduce the potential for resuspension and mobilization of contaminated sediments. However, during any dredging or excavation action, some disturbed, contaminated material often remains at the new surface—this material is referred to as “residuals.” Residuals can affect the dredged or excavated area as well as nearby surrounding areas. BMPs during dredging would reduce the generation of residuals. The following paragraphs discuss how any remaining residuals would be managed after the dredging.

Under Alternative 4, residuals management issues and approaches would generally be as described for Alternative 3. However, because Alternative 4 includes a greater volume and area of dredging near the southern EAA boundary, the potential need for residual management actions outside the EAA boundary is greater than Alternative 3. For cost-estimating purposes, it is assumed that contingency actions would include 1–2 feet of additional dredging in the inner berth area and placement of up to 3,000 cy of additional cap material for enhanced natural recovery. The enhanced natural recovery material is assumed to be required in both the inner berth area and an area extending approximately 200 feet south of the removal boundary.

As with Alternative 3, the feasibility of using enhanced natural recovery south of the removal area would require further evaluation in design. A portion of this area is the permitted dredge prism of Crowley’s middle berth, and placement of material for enhanced natural recovery may interfere with navigation or increase future maintenance dredging costs.

Material Handling, Transportation, and Disposal

Materials handling, transportation, and disposal would be as described for Alternative 1.

Construction Approach

The construction approaches for Alternative 4 would be as described for Alternative 3.

Institutional Controls

Institutional controls for Alternative 4 would be as described for Alternative 3.

Monitoring, Maintenance, and Reviews

Long-term monitoring, maintenance, and periodic reviews would be implemented as described for Alternative 1.

Summary of Construction Quantities

The estimated volumes of bank excavation, dredging, and capping associated with Alternatives 1 through 4 are summarized in Table 5-1.

5.4.2 Evaluation of Alternative 4

An initial evaluation of Alternative 4 is provided below. Section 6 includes a more detailed comparative analysis of the four alternatives.

Effectiveness: Alternative 4 would be effective in removing and containing sediments with PCBs and other chemicals of interest within the Slip 4 removal area. Both removal and capping are proven technologies that have been successfully implemented in similar CERCLA sediment cleanup actions. Alternative 4 satisfies the RAO for the Slip 4 removal area by creating a post-construction surface that meets the SQS chemical criteria and providing effective long-term containment of remaining material. By meeting the cleanup standards, Alternative 4 would be protective of human health and the environment. Land use restrictions, long-term monitoring, and periodic reviews would ensure long term protection of human health and the environment.

Alternative 4 could be implemented in compliance with all ARARs. ARARs related to habitat [including CWA 404(b)(1) requirements and ESA requirements] are of particular relevance to the Slip 4 removal action, because Slip 4 is important aquatic habitat to several species including threatened Puget Sound chinook and Coastal/Puget Sound bull trout. These ARARs include:

- CWA 404(b)(1) evaluation guidelines include assessing the potential effects of the cleanup on physical and chemical characteristics, biological characteristics, and particular habitat types. Alternative 4 is acceptable under the 404(b)(1) guidelines with the following considerations:
 - The dredging, backfilling, and capping activities would create no net loss of aquatic habitat.
 - The final surface sediment chemistry would be improved to meet Washington State SMS.
 - Dredging of the inner berth would decrease lower intertidal and shallow subtidal habitat acreage relative to existing conditions. The dredging would approximately restore historically permitted conditions.
 - The backfill and cap materials would require significant armoring.

- Compliance with ESA would be evaluated as described for Alternative 1. The dredging and capping activities under Alternative 4 may have some adverse impacts to habitat, but are not expected to jeopardize the continued existence of threatened and/or endangered species. Where possible, the backfill and cap design would incorporate habitat enhancement features to improve habitat for threatened Puget Sound chinook and Coastal/Puget Sound bull trout, consistent with ESA goals. Specific effects of the alternatives on habitat acreages and elevations are discussed further in Section 6

Alternative 4 would remove a total of approximately 40,000 cy of sediments and soils containing PCBs, and dispose of this material in a permitted upland landfill approved by EPA. Remaining impacted material would be reliably contained by capping. Alternative 4 does not include treatment to reduce the toxicity, mobility, or volume of contaminants.

Alternative 4 can likely be implemented in one construction season, although it is possible that an extension to the allowable in-water work period may be needed. The RAO would be achieved upon completion of construction. The institutional controls could be fully implemented within approximately 1 year of construction completion. Engineering controls, BMPs, and other measures to ensure compliance with ARARs would control short-term risks during implementation. Under Alternative 4, dredging would occur up to the southern removal area boundary, hence creating some potential for dredging residuals to affect a limited area south of the removal area boundary. Dredging residuals in the inner berth may exceed the SQS even after several dredging passes. Confirmation sampling and contingency actions would be employed as needed to address residuals.

Alternative 4 would remove most of the contaminated sediments from the Slip 4 EAA, but some contamination would remain in under-pier areas, within the slip near the toes of embankments, and within embankments. Alternative 4 relies on containment through capping for reliable long-term physical and chemical isolation of contaminated sediments that would remain. Caps would be designed for long-term function, and long-term performance would be verified through monitoring and periodic reviews. Land use restrictions would also contribute to the long-term integrity of the caps by reliably minimizing the potential for future uncontrolled activities that could disturb the caps.

Under Alternative 4, caps surrounding the inner berth may be subject to significant erosive forces from propeller wash. Although caps would be designed to resist these erosive forces, some additional long-term cap monitoring and/or maintenance may be required. Furthermore, future maintenance dredging that may be required in the inner berth would require specific controls to minimize the potential for cap damage and maximize long-term reliability.

Implementability: Based on the proven success of similar EPA Region 10 removal/capping projects, Alternative 4 can reliably be implemented using commonly available upland and marine construction equipment and materials. Excavated materials can readily be trucked or barged offsite and imported material brought onsite with conventional trucking or barge equipment. A small portion of the excavation under Alternative 4 could be completed when the tides are out, allowing easier control of the work and further limiting releases to the water column during excavation. For the bank work, the contractor would schedule excavation and capping activities to take best advantage of low tides to accomplish work in-the-dry. The remainder of the work (including most dredging and capping) would be completed using floating equipment and conventional marine construction methods, working at higher tides as needed to provide the required draft for the barges.

Dredged or excavated materials would be either loaded onto trucks onsite or loaded onto conventional barges and moved offsite. The material from barges would be offloaded to either rail cars or trucks at a rehandling facility in the project vicinity.

While Alternative 4 can be reliably implemented, actions in the inner berth area would require special consideration of design, monitoring, and construction elements:

- Attaining SQS in the inner berth will require specific construction sequencing approaches and may result in contractor downtime. Two or more dredging passes would be required to attain a clean surface in the inner pier area. Sequencing the dredging relative to actions in adjacent areas is critical, and additional contingency measures, such as overdredging and enhanced natural recovery, may be required in the inner berth area. Similar contingency measures could be required in the area south of the removal boundary. Sequencing requirements and time required for confirmation sampling and analyses may result in downtime.
- Removal of under-pier sediments and placement of under-pier cap material may pose construction difficulties. Removal and replacement of fender piles will likely be required to improve access. A barge-mounted excavator would likely be used to move most under-pier sediments, as practicable. The same equipment or a conveyor would likely be used to place under-pier cap material. Due to limited overhead clearance, specific equipment selection and timing of the work for lower tides would be critical.

Most of the work for Alternative 4 would be completed on submerged land owned by Crowley Marine Services. Portions of the Zone 3, 4, and 5 bank work (above +10 feet MLLW) would extend onto property owned by First South Properties. A small portion of the Zone 5 bank work may extend onto property owned by The Boeing Company. Land access and staging areas would be required on property owned by First South Properties. The City is coordinating with these property owners to arrange access and staging areas

during the work, implement land-use restrictions for long-term protection of the capped area, and provide easements allowing access for future long-term monitoring activities.

Cost: The estimated removal action cost for Alternative 4 is detailed in Table 5-5. The total estimated costs include present-value O&M costs estimated for 30 years, based on a 5 percent discount rate. Over the 30-year period, operation costs assume seven monitoring events, and maintenance costs assume four cap repair events. O&M costs were not projected beyond 30 years because their effect on net present value becomes diminishingly small.

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6 COMPARATIVE ANALYSIS OF REMOVAL ACTION ALTERNATIVES

This section presents a comparative analysis of the four removal action alternatives for Slip 4. Consistent with EPA (1993) guidance, the analysis is based on a comparison of effectiveness, implementability, and cost with regard to the following specific criteria:

- Effectiveness
 - Overall protection of human health and the environment
 - Achievement of RAOs
 - Compliance with ARARs
 - Reduction of toxicity, mobility, or volume through treatment
 - Short-term effectiveness
 - Long-term effectiveness and permanence
- Implementability
 - Technical feasibility
 - Availability
 - Administrative feasibility
- Cost
 - Capital cost
 - Present worth of long-term monitoring and maintenance
 - Total present-worth cost.

The following subsections analyze the alternatives based on the EPA criteria. Section 6.4 summarizes the analysis and includes a relative ranking of the alternatives for each criterion.

6.1 EFFECTIVENESS

6.1.1 Overall Protection of Human Health and the Environment

All four removal action alternatives would reduce risks to human health and the environment over the long term through a combination of removal of soil and sediment contaminated with PCBs and other co-occurring contaminants, and containment of remaining contaminated soil and sediment with engineered caps. Each alternative would achieve the RAO and comply with all ARARs. Each alternative employs removal and

capping technologies that are reliable and proven technologies that have been used successfully in similar sediment cleanup actions at EPA Superfund sites.

Under each alternative, some hazardous substances would remain onsite (contained beneath engineered caps) at levels that do not allow unlimited use and unrestricted exposure. Each alternative would include monitoring and periodic reviews to verify long-term protection of human health and the environment. Each alternative would also include land use restrictions as an additional means of maintaining long-term protection of human health and the environment. The land use restrictions would contribute to the long-term integrity of the caps by reliably minimizing the potential for future uncontrolled activities that could disturb the caps.

6.1.2 Achievement of RAOs

Each of the alternatives would satisfy the RAO for the Slip 4 removal area by creating a post-construction surface that meets the cleanup standards and providing effective long-term containment of remaining material with engineered caps.

In addition to the specific Slip 4 NTCRA RAO, the NCP [40 CFR 300.415(c)] states that removal actions shall, to the extent practicable, contribute to the efficient performance of any anticipated long-term remedial action with respect to the release concerned. Each of the alternatives would be compatible with potential long-term remedial actions for the LDW. Additionally, none of the alternatives is expected to preclude possible mitigation projects in nearby areas should such projects be identified in the future.

6.1.3 Compliance with ARARs

Consistent with the NCP, each of the alternatives would satisfy the substantive requirements of all ARARs. None of the alternatives would require waivers of any ARARs.

Table 6-1 is a comprehensive list of ARARs for the Slip 4 removal action. In addition to the ARARs identified in Table 6-1, the Point Elliott Treaty of 1855 (while not an ARAR) is to be considered in design. The United States, including federal agencies, has a duty to protect treaty fishing rights reserved by Native American tribes and defined by court decisions and orders. Under the 1855 Treaty of Point Elliott, tribes ceded certain of their aboriginal lands to the United States but reserved under the treaty “the right of taking fish at all usual and accustomed grounds and stations.” Caps will be designed to avoid the need for any shellfish harvest restrictions. In consultation with the tribes, the selected alternative will be designed to minimize any adverse effects on fish and shellfish harvesting in Slip 4.

Additional discussion on ARAR compliance is provided below for selected ARARs, including SMS, CWA, and ESA.

6.1.3.1 Washington State Sediment Management Standards (WAC 173-204)

The SMS include numeric chemical standards for total PCBs in sediment. These standards are applicable to the removal action. Under each alternative, the post-construction surface sediment concentrations within the removal boundary will be at or below the SQS chemical criteria of the SMS (WAC 173-204-320) for all chemicals of interest. These concentration goals have been developed on a site-specific basis for Slip 4, consistent with the requirements of the SMS (WAC 173-204-570). Attaining these concentrations in surface sediments (0–10 cm) represents compliance with the SMS. Each alternative will also result in a new sediment surface throughout Slip 4 that will be as clean as or cleaner than the existing surface, and therefore will comply with SMS anti-degradation requirements of WAC 173-204-120.

6.1.3.2 Sections 401 and 404 of the Federal Clean Water Act—Water Quality Certification and Dredge and Fill Requirements (33 USC 1340, 1344; 33 CFR Parts 320 through 330 and 40 CFR Parts 230 and 231)

CWA Sections 401 and 404 requirements for water quality certification and dredging and filling materials in waters of the U.S., respectively, are applicable to in-water actions at Slip 4. Because these actions will take place onsite, only substantive requirements of these programs apply.

Section 401 requires that a certification of water quality be issued by the responsible government authority to state that remedial operations will not violate applicable water quality standards. EPA will examine the removal design and, as a result of that review, will make a determination regarding the ability of the project to meet State water quality criteria. EPA will prepare a CWA Section 401 Water Quality Certification, which will specify allowable in-water work periods, water quality monitoring requirements and compliance criteria, and operational responses should any exceedances of water quality criteria occur. Under each alternative, all in-water work would be conducted and monitored in accordance with EPA's 401 certification. The contractor would be required to modify operations or employ other engineering measures (e.g., use different equipment or silt curtains) as needed to remain in compliance with water quality criteria. Each alternative can be implemented in compliance with the 401 certification requirements.

EPA will complete a Section 404(b)(1) evaluation for the selected removal alternative to determine whether the in-water cleanup work will comply with the requirements of the Section 404 program. Specifically, the 404(b)(1) guidelines (at 40 CFR 230) consider the following:

- Potential impacts on physical and chemical characteristics
- Potential impacts on biological characteristics of the aquatic ecosystem
- Potential impacts to special aquatic sites (including mudflats and vegetated shallows)

- Potential effects on human use characteristics
- Evaluation and testing of dredge and fill materials
- Actions to minimize adverse effects.

Overall, Alternatives 1 and 2 rank favorably under the 404(b)(1) guidelines because:

- The dredging and capping activities would create a small net gain in total aquatic habitat area.
- There would be net gains in intertidal and shallow subtidal habitat areas relative to both existing and historically permitted conditions.
- The cap materials would require comparatively little armoring.
- The final surface sediment chemistry would be improved to meet Washington State SMS.

Alternatives 3 and 4 would be acceptable under the 404(b)(1) guidelines because:

- The dredging, capping, and backfilling activities would create no net loss of aquatic habitat.
- The final surface sediment chemistry would be improved to meet Washington State SMS.

However, Alternatives 3 and 4 are less favorable than Alternatives 1 or 2 under the 404(b)(1) guidelines because:

- Dredging of the inner berth would decrease lower intertidal and shallow subtidal habitat acreage relative to existing conditions. The dredging would approximately restore historically permitted conditions.
- There would be no net gain in total aquatic habitat area.
- The backfill and cap materials would require significant armoring.

As discussed in Section 2, Slip 4 is a net depositional environment. Under each alternative, accumulations of fine-grained sediments are expected to deposit on top of the constructed cap surface over time. This sediment deposition will change the post-construction substrate over time, affecting the types and abundance of organisms that live in the sediments. The fine-grained deposits may improve habitat quality over time, even in areas with cap armoring. Under Alternatives 3 and 4, this deposition is expected to shoal the inner berth area, which will eventually necessitate future maintenance dredging.

In summary, each alternative is expected to comply with all CWA 404 requirements. Specific effects of each alternative on the distribution of habitat elevations is discussed as part of the ESA evaluation in the following subsection.

6.1.3.3 Endangered Species Act (16 USC 1531 et seq.; 50 CFR Parts 17, 200, 402)

ESA requirements are applicable to the removal action. Section 7 of the ESA requires that federal agencies consider the effect of proposed actions on federally threatened or endangered species. As noted in Section 2.1.8.2 of this EE/CA, several federally threatened and/or endangered wildlife and fish species may be present in the site area. EPA will consult with the NOAA Fisheries and USFWS about the potential effects of removal activities and ways to minimize those effects. For this consultation, a biological assessment will be completed as part of the removal design process to assess the potential effects of removal activities and ways to minimize adverse effects.

Once the biological assessment is complete, NOAA Fisheries and USFWS will issue a biological opinion as to whether the activity as proposed would jeopardize the existence of the listed species. If so, they may suggest conservation measures that if followed would reduce adverse project effects below the “jeopardy” threshold and allow the activity to proceed. If a no jeopardy opinion is issued, the activity may be conducted as planned.

Each of the removal action alternatives is expected to be beneficial to threatened Puget Sound chinook and Coastal/Puget Sound bull trout by greatly reducing their potential exposure to PCBs. Each alternative would result in no net loss of aquatic habitat acreage. Each alternative would result in some conversions between elevation ranges, including sublittoral (deeper than -10 feet MLLW), shallow subtidal (-10 to -4 feet MLLW), lower intertidal (-4 to +4 feet MLLW), and upper intertidal (+4 to +12 feet MLLW). Table 6-2 summarizes the surface area within different elevation ranges for the existing conditions, historically permitted conditions, and for Alternatives 1 through 4.

The changes in elevation distributions and habitat function can be evaluated both against the existing conditions and the historically-permitted conditions (when the inner berth was deepened to a permitted depth of -15 feet MLLW in 1981). For the purposes of this comparative analysis, the changes under each alternative are discussed relative to the existing conditions. However it should be noted that the historically-permitted conditions represent an existing allowable use, and the deepening of the slip under Alternatives 3 and 4 would likely be evaluated against historically permitted conditions when determining whether any compensatory mitigation is needed. Table 6-3 summarizes the net changes in habitat areas under each alternative relative to existing conditions.

Appendix C presents the approximate elevation contours of the final constructed surface under each alternative. For all alternatives, accumulations of fine-grained sediments are expected to deposit on top of the constructed cap surface over time. This sediment deposition is expected to result in a gradual net shallowing of the slip over time, and is a continuation of existing sediment transport processes in the LDW.

As shown in Tables 6-2 and 6-3, there are significant differences in habitat elevation distributions among the alternatives. Relative to existing conditions:

- Alternative 1 would expand shallow subtidal habitat by approximately 0.35 acres and expand total intertidal habitat by approximately 0.41 acres, but would decrease lower intertidal (-4 to +4 feet MLLW) habitat area by approximately 0.41 acres. Alternative 1 creates 0.06 acres of new aquatic habitat.
- Alternative 2 would expand shallow subtidal habitat by approximately 0.26 acres and expand intertidal habitat by approximately 0.54 acres. Lower intertidal (-4 to +4 feet MLLW) habitat area would expand by approximately 0.05 acres. Alternative 2 creates 0.08 acres of new aquatic habitat.
- Alternative 3 would decrease the shallow subtidal habitat area by approximately 0.37 acres. The total intertidal habitat area would approximately equal the existing area, but the lower intertidal (-4 to +4 feet MLLW) area would decrease by approximately 0.29 acres.
- Alternative 4 would decrease the shallow subtidal habitat area by approximately 0.37 acres. The total intertidal habitat area would approximately equal the existing area, but the lower intertidal (-4 to +4 feet MLLW) area would decrease by approximately 0.26 acres.

Alternatives 1 and 2 would substantially increase both intertidal and shallow subtidal habitat areas compared to both existing conditions and historically permitted conditions. These increases result primarily from conversion of equivalent sublittoral acreages (i.e., shallowing of the slip through capping) and, to a lesser extent, from excavation of bank and upland areas.

In contrast, Alternatives 3 and 4 would convert approximately 0.36–0.39 acres of existing intertidal and shallow subtidal habitat to sublittoral habitat, generally deepening the slip by dredging the inner berth. Alternatives 3 and 4 approximately restore the habitat distribution associated with historically permitted conditions (i.e., the conditions following the 1981 dredging of the inner berth).

In summary, Alternatives 1 and 2 would result in net gains in intertidal, shallow subtidal, and total aquatic habitat relative to both existing and historically permitted conditions, thereby providing additional habitat for threatened Puget Sound chinook and Coastal/Puget Sound bull trout. Under Alternatives 3 and 4, the inner berth would be approximately restored to historically permitted conditions, which would decrease existing intertidal and shallow subtidal habitat acreage for these species. Also, the additional armoring that would be required under Alternatives 3 and 4 may result in a less desirable substrate in the remaining intertidal areas.

While there are significant differences in habitat quality and quantity among the alternatives, it is anticipated that each of the alternatives could be implemented in compliance with ESA requirements. None of the alternatives are expected to jeopardize the continued existence of threatened and/or endangered species.

6.1.4 Long-term Effectiveness and Permanence

Alternatives 1 and 2 include partial excavation of PCB-contaminated sediments and soil, followed by capping throughout the entire Slip 4 EAA. Alternative 3 includes potentially complete removal of contaminated sediments in the inner berth area, partial removal outside of the inner berth area, and capping under the pier and outside of the inner berth area. Alternative 4 includes removal of most of the contaminated sediments from the Slip 4 EAA, but some contamination would remain in under-pier areas, within the slip near the toes of embankments, and within embankments.

Each of the alternatives relies on containment through capping for reliable long-term physical and chemical isolation of contaminated sediments that would remain in the Slip 4 removal area. Caps would be designed to remain stable and provide long-term containment in accordance with EPA/USACE guidance. Caps would also be designed for long-term seismic stability. Long-term reliability of the caps would be verified through LTMRP that requires periodic monitoring and repair of the cap if needed. The long-term effectiveness would also be assessed through periodic reviews, no less frequently than every five years. Land use restrictions would also contribute to the long-term integrity of the caps by reliably minimizing the potential for future uncontrolled activities that could disturb the caps.

Under Alternative 1, near-surface material containing the highest concentrations of PCBs would remain in the head of the slip. This material can be effectively capped, and the potential for release of underlying sediments (e.g., from complete erosional failure of the cap) is small. However, the consequences of cap failure in this area may be greater than under the other alternatives. Alternative 1 would eliminate future navigational use of the EAA by heavy tugs, greatly reducing the potential for significant cap erosion by propeller wash.

Under Alternative 2, sediments containing the highest concentrations of PCBs would be removed from the slip before capping, providing greater long-term effectiveness than Alternative 1. Also, the targeted removal under Alternative 2 would eliminate areas where comparatively high PCB concentrations immediately underlie the cap. Remaining material that exceeds the CSL would generally be contained under existing layers of cleaner sediments, which in turn would be contained by engineered cap materials. These cleaner sediment deposits beneath the cap would enhance the long-term cap performance by providing an additional barrier to any contaminant transport. Alternative 2 would

also eliminate future navigational use of the EAA by heavy tugs, greatly reducing the potential for significant cap erosion by propeller wash.

Under Alternative 3, significantly more contaminated sediment would be removed compared to Alternatives 1 and 2. However, under Alternative 3, caps surrounding the inner berth may be subject to significant erosive forces from propeller wash associated with the restored navigable use of the inner berth. Although caps would be designed to resist reasonably anticipated erosive forces, the need for long-term cap maintenance may be greatest under Alternative 3. Periodic maintenance dredging of the inner berth would likely be required, as sediments naturally accumulate in the berth. Historical shoaling rates suggest such dredging could be required every 10–20 years. In addition to the substantial natural sedimentation rate in this area, any erosion of nearby cap materials may contribute to shoaling in the inner berth. Future maintenance dredging would need to be carefully designed and monitored to minimize the potential for cap damage. Future costs for potential maintenance dredging are assumed to be the responsibility of the land owner.

Alternative 4 would remove most of the contaminated sediments from the Slip 4 EAA, but some contamination would remain in under-pier areas, within the slip near the toes of embankments, and within embankments. Caps and backfill surrounding the inner berth may be subject to significant erosive forces from propeller wash associated with the restored navigable use of the inner berth. Although caps and backfill would be designed to resist reasonably anticipated erosive forces, some long-term cap maintenance may be required under Alternative 4. As with Alternative 3, maintenance dredging of the inner berth would likely be required, perhaps every 10–20 years. Future costs for potential maintenance dredging are assumed to be the responsibility of the land owner.

6.1.5 Reduction of Toxicity, Mobility, or Volume through Treatment

None of the alternatives involves treatment. The reduction of toxicity, mobility, or volume through treatment is not considered practicable for the Slip 4 removal action because of substantial limitations regarding effectiveness, implementability, and cost (see Section 4.5).

6.1.6 Short-term Effectiveness

Alternatives 1 and 2 can be implemented in one construction season, and the RAO would be achieved upon completion of construction. Alternatives 3 and 4 can likely be implemented in one construction season; however, the time needed for construction may approach the limits of the in-water construction window. It is possible that an extension of the allowable period of in-water work could be required under Alternatives 3 and 4—such an extension would be coordinated with the agencies, if needed. Under each alternative, the institutional controls could be fully implemented within approximately 1 year of construction completion.

None of the alternatives poses significant short-term risks to the community during implementation. It is anticipated that most material transport would occur by barge; however, some truck traffic through industrial areas may be needed for offsite disposal and/or importing clean backfill. Risks to workers during implementation would be managed through standard engineering and safety controls.

Short-term risks to the environment during implementation would be limited through engineering controls, BMPs, and other measures to ensure compliance with ARARs (e.g., observance of fish windows). Under Alternatives 1 and 2, the potential for releases of material to the environment during construction would be minimal because a relatively small volume of contaminated material would be excavated or dredged, much of the excavation would occur in-the-dry, and all surrounding areas would subsequently be capped. Under Alternatives 3 and 4, dredging would occur up to the southern removal area boundary, and hence there is some potential for dredging residuals to affect a limited area south of the removal area boundary. Monitoring and contingency actions (potentially including additional dredging or enhanced natural recovery) would be employed as needed to address residuals under Alternatives 3 and 4. Short-term impacts to water quality would be of greater duration under Alternatives 3 and 4, as several additional weeks of dredging would be required.

Soils and sediments with intermediate concentrations of PCBs are present in the Zone 3, 4, and 5 embankments. Each alternative would include measures to limit releases of contaminated materials from the banks during implementation. Bank excavations would proceed from the top of the bank downward, would occur when the tides are out (as practicable), and the excavated face would be capped soon after it is exposed.

For each alternative, the design would specify requirements for environmental protection during excavation, dredging, and capping activities.

6.2 IMPLEMENTABILITY

6.2.1 Technical Feasibility

Sequencing of the work would be critical for successful implementation of any alternative. Each alternative would be sequenced to limit the potential for water-borne sediment transport and recontamination of areas outside the removal boundary or areas that have already been cleaned up. The implementation of both Alternatives 1 and 2 would likely be based on the following general sequencing:⁷

⁷ The general construction sequencing discussions for the alternatives are preliminary and are intended to illustrate comparative differences in sequencing requirements among the alternatives. Specific sequencing requirements will be developed in the design.

- Cleanout of Georgetown flume sediments
- Excavation of the Zone 2, 3, 4, and 5 embankments, and capping of the Zone 5 embankment (working in-the-dry as practicable)
- Excavation/dredging of mudflat areas at the head of Slip 4, with immediate stabilization through cap placement near outfalls
- Capping of the Zone 2, 3, and 4 embankments
- Cap placement proceeding from the head of Slip 4 and moving south.

The implementation of Alternatives 3 and 4 would likely be based on the following general sequencing:

- Cleanout of Georgetown flume sediments
- Excavation of the Zone 3, 4, and 5 embankments, and capping of the Zone 5 embankment (working in-the-dry as practicable)
- Excavation/dredging of areas outside the inner berth, with immediate stabilization near outfalls through cap material placement
- Dredging of inner berth and under-pier area
- Second-pass dredging in inner berth and confirmation sampling in the inner berth and south of the removal boundary
- Capping of the Zone 3/4 embankment
- Cap placement proceeding from the head of Slip 4 and moving south (including under-pier area)
- Implementation of contingency actions for residuals management, as required based on confirmation sampling.

The more restrictive sequencing required under Alternatives 3 and 4 could necessitate some construction downtime and project delays, and the cost estimates for Alternatives 3 and 4 reflect this possibility. Under all of the alternatives, documentation sampling of excavated banks would be completed prior to cap placement; however, the bank capping could proceed before sample results were reported.

For work on the banks, the contractor would schedule excavation and capping activities to take best advantage of low tides to accomplish work in-the-dry as practicable. However, it may not be feasible to accomplish all of the bank work in-the-dry. The remainder of the work (including most dredging and capping) would be completed using floating equipment and conventional marine construction methods, working at higher tides as needed to provide the required draft for the barges.

Sequencing will be further addressed during design, including development of provisions to protect and monitor sediment quality in completed areas of the site from the impacts of subsequent work in adjacent areas.

While Alternatives 3 and 4 can be reliably implemented, actions in the inner berth area would require greater consideration of design, monitoring, and construction elements than Alternatives 1 or 2. These elements include the following:

- Attaining SQS in the inner berth will require specific construction sequencing approaches and may result in contractor downtime. Two or more dredging passes would be required to attain a clean surface in the inner pier area, sequencing the dredging relative to actions in adjacent areas is critical, and additional contingency measures such as overdredging and enhanced natural recovery may be required in the inner berth area. Similar contingency measures could be required in the area south of the removal boundary. Sequencing requirements and time required for confirmation sampling and analyses may result in some project delays and associated costs.
- Removal of under-pier sediments and placement of under-pier cap material may pose construction difficulties. Removal and replacement of fender piles will likely be required to improve access. A barge-mounted excavator would likely be used to remove most under-pier sediments, as practicable. The same equipment or a conveyor would likely be used to place under-pier cap material. Due to limited overhead clearance, specific equipment selection and timing of the work for lower tides would be critical.

6.2.2 Availability

Each of the alternatives can reliably be implemented using commonly available upland and marine construction equipment and materials. Dredged or excavated materials would be either loaded onto trucks onsite or loaded onto conventional barges and moved offsite. The material from barges would be offloaded to either rail cars or trucks at a rehandling facility in the project vicinity. Imported material can be brought onsite with conventional trucking or barge equipment. Numerous local contractors are experienced in this type of work. The volume of contaminated sediments that would be shipped offsite for upland landfill disposal is not anticipated to impact the capacity of the receiving facilities.

6.2.3 Administrative Feasibility

Under Alternatives 1 or 2, the City would negotiate with Crowley Marine Services to purchase or otherwise acquire rights to the property depicted in Figure 5-1, covering most of the land in the Slip 4 EAA. This land acquisition is required for implementation of Alternatives 1 or 2. It is considered to be administratively feasible and is not expected to delay cleanup. Under Alternatives 3 and 4, most of the work would be completed on submerged land owned by Crowley Marine Services.

For all alternatives, portions of the bank work (above +10 feet MLLW) would extend onto property owned by First South Properties. A small portion of the Zone 5 bank work may extend onto property owned by The Boeing Company. Land access and staging areas would be required on property owned by First South Properties. The City is coordinating with these property owners to arrange access and staging areas during the work, implement land-use restrictions for long-term protection of the capped area, and provide easements allowing access for future long-term monitoring activities. Institution controls that will limit any uncontrolled disturbance of capped areas will be developed as part of the design process, as described in Section 5. Although the specifics would vary among the alternatives, the institutional controls are considered to be administratively feasible for each alternative.

6.3 COST

The estimated costs for removal Alternatives 1, 2, 3, and 4 are \$6,000,000, \$6,900,000, \$8,700,000 and \$11,200,000, respectively, based on present value,⁸ including long-term monitoring and maintenance costs⁹ for the capping components of the cleanup.

6.4 SUMMARY OF COMPARATIVE ANALYSIS

Table 6-4 presents a comparison of the removal alternatives. This analysis is summarized below, and the four removal alternatives are ranked relative to one another for effectiveness, implementability, and cost:

- **Effectiveness:** The effectiveness evaluation considers overall protection of human health and the environment, achievement of RAOs, compliance with ARARs, reduction of toxicity, mobility, or volume through treatment, short-term effectiveness, and long-term effectiveness and permanence. For overall effectiveness, Alternative 2 ranks highest, followed by Alternatives 1, 4, and 3. Each alternative would provide overall protection of human health and the environment and can achieve the RAO. Each alternative can be implemented in compliance with ARARs. Alternative 2 provides the greatest quantity and highest quality habitat for threatened Puget Sound chinook and Coastal/Puget Sound bull trout, with Alternative 1 providing slightly less habitat benefits. Alternatives 1 and 2 would both expand shallow subtidal, intertidal, and total aquatic habitat areas. Alternatives 3 and 4 would significantly decrease shallow subtidal and intertidal habitat area and would require more armoring, which may decrease habitat quality. Alternatives 1 and 2 are similar in their short-term effectiveness and are not expected to pose significant recontamination risk outside the removal area. Due to the greater amount of dredging and longer project duration,

⁸ Net Present Value analysis based on 2007 year 0 and 5 percent net discount rate.

⁹ Long-term monitoring costs based on seven events over 30 years. Maintenance costs based on assumed cap repairs associated with erosion potential.

Alternatives 3 and 4 would pose a greater short-term risk of recontamination caused by dredging and would have greater short-term water quality impacts during dredging. Each alternative would be effective in the long-term; however, the consequences of possible cap erosion would be greatest under Alternative 1. The potential for erosion is greatest under Alternatives 3 and 4 (due to navigation), and hence Alternatives 3 and 4 may require somewhat greater maintenance over the long-term. Each alternative would include institutional controls, long-term monitoring, and periodic reviews to ensure long-term protectiveness.

- **Implementability:** The implementability evaluation considers the technical and administrative feasibility of implementation, as well as the availability of materials, equipment, and services. For overall implementability, Alternatives 1 and 2 rank highest, followed by Alternatives 3 and 4. Each of the alternatives can reliably be implemented; however, Alternatives 3 and 4 would require special consideration of design, monitoring, and construction elements so that a clean sediment surface is left in the inner berth and in adjoining areas south of the removal boundary. Under Alternatives 3 and 4, removal of under-pier sediments and placement of under-pier cap material would also require special provisions.
- **Cost:** The cost evaluation considers capital costs, long-term monitoring and maintenance costs, and total present worth costs. Alternative 1 is the least expensive alternative, followed by Alternatives 2, 3, and 4. Alternative 2 would cost approximately 15 percent more than Alternative 1. Alternative 3 would cost roughly 50 percent more than Alternative 1. Alternative 4 would cost roughly twice as much as Alternative 1.

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7 RECOMMENDED REMOVAL ACTION ALTERNATIVE

Alternatives 1 through 4 for the Slip 4 removal action are each considered effective and would each satisfy the ARARs and the RAO identified for the project. The City and County recommend Alternative 2 for the following reasons:

- Alternative 2 removes material containing the highest PCB concentrations from Slip 4 and reliably contains the remaining contaminated materials with engineered caps. In the unlikely event of significant cap erosion, the potential for recontamination of surrounding areas is much lower compared to Alternative 1.
- Compared to Alternatives 3 and 4, Alternative 2 has a lower potential for releases of contaminated material to surrounding areas during construction and lesser short-term impacts to water quality.
- Alternative 2 results in the greatest habitat benefits among the alternatives. Relative to existing conditions, Alternative 2 expands shallow subtidal habitat by approximately 0.26 acres and expands intertidal habitat by approximately 0.54 acres. Alternative 2 creates 0.08 acres of new aquatic habitat. Alternative 1 would expand shallow subtidal, intertidal, and total aquatic habitat by similar amounts, but would decrease lower intertidal (-4 to +4 feet MLLW) habitat by approximately 0.41 acres. In contrast, Alternatives 3 and 4 would both decrease existing shallow subtidal habitat by approximately 0.37 acres and decrease existing lower intertidal habitat by approximately 0.26–0.29 acres.
- Alternative 2 requires less armoring than Alternatives 3 and 4, and therefore the quality of habitat would be higher.
- Alternative 2 requires less long-term maintenance and is easier to implement compared to Alternatives 3 and 4.

In summary, Alternative 2 represents the most practical and cost-effective balance of contaminant removal and containment while maximizing long-term effectiveness, preserving habitat, and minimizing potential long-term O&M requirements.

Once an alternative is selected by EPA, the City and King County will conduct a predesign investigation to fill any remaining data gaps needed for design of the selected alternative. For Alternative 2, these investigations may include a physical conditions survey (including debris assessment), additional evaluation of Zone 2 bank soil chemistry, additional physical and/or chemical characterization of material targeted for removal, geotechnical investigations, and potentially additional seep sampling. Additionally, bank soil and sediment data and geophysical features within the southern portion of the Zone 5

embankment on Boeing property will be evaluated and EPA will determine whether additional sampling should occur as part of predesign efforts to confirm the cleanup boundary in this area. The specific data needs would be determined, as approved by EPA, once the remedy is selected.

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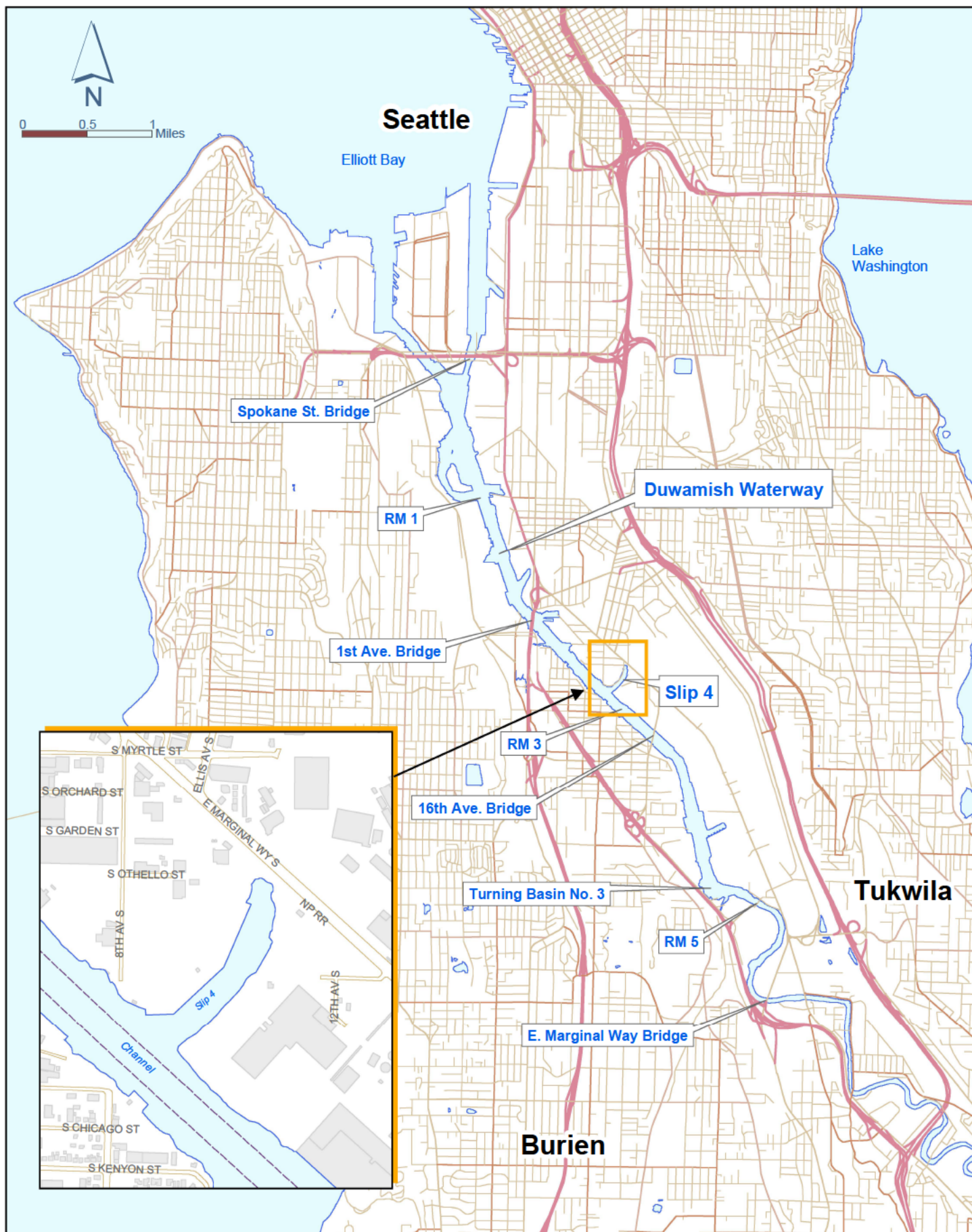
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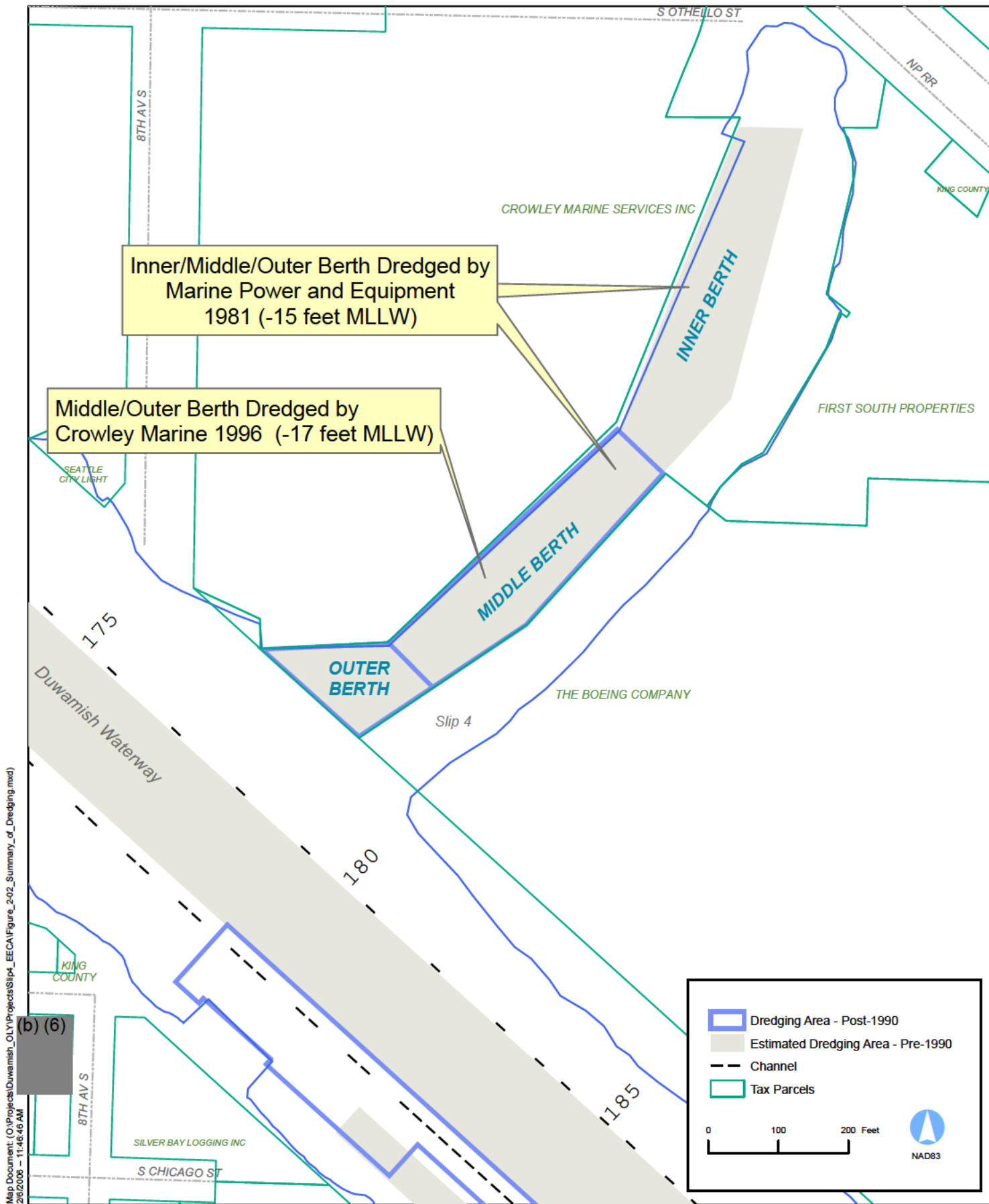
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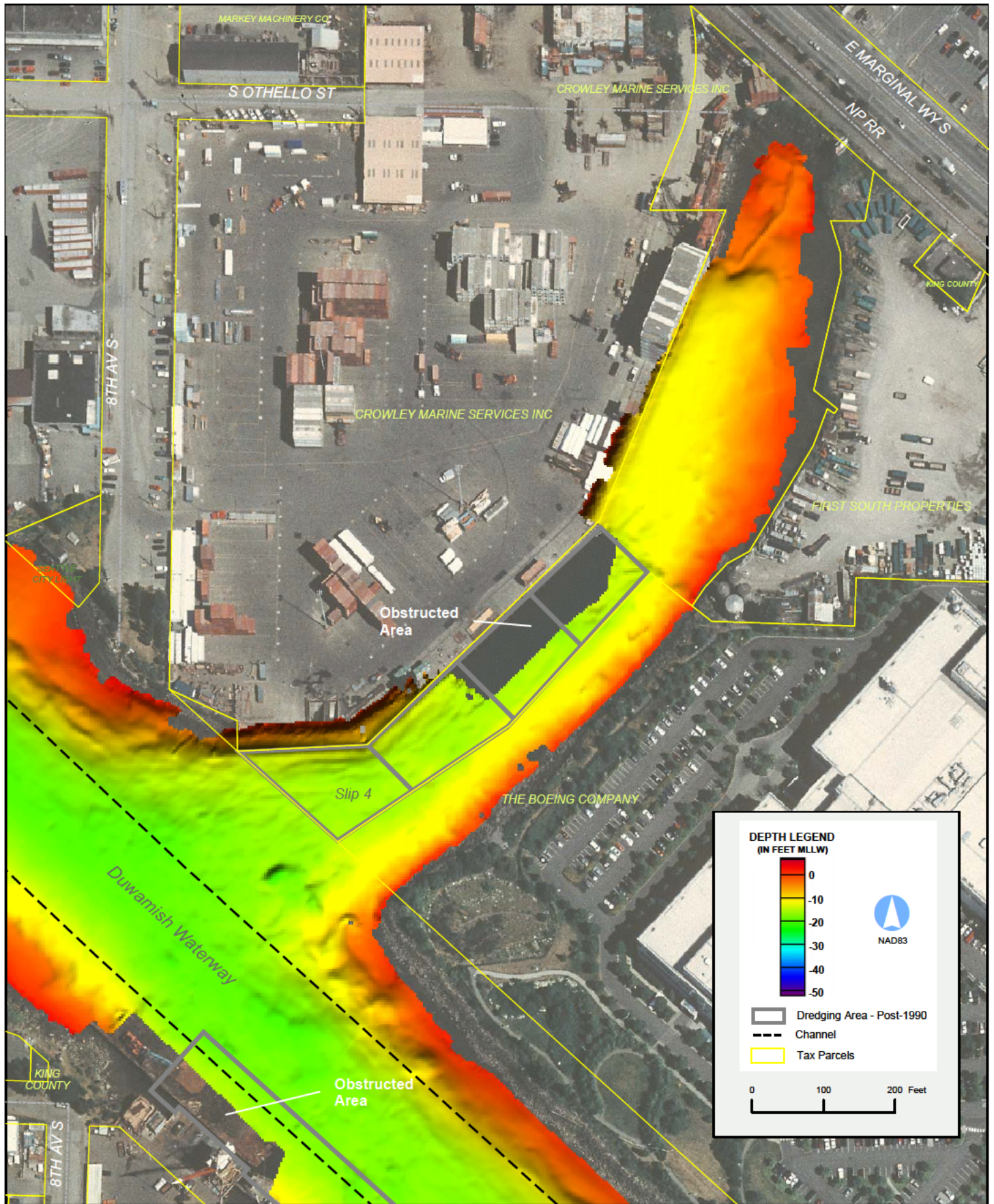
Windward and QEA. 2004. Quality Assurance Project Plan: Sediment Transport Characterization. Final. Windward Environmental, LLC, Seattle, WA.

Windward, Dalton, Olmsted & Fuglevand, and Onsite Enterprises. 2005. Terminal 117 Engineering Evaluation/Cost Analysis. Submitted to U.S. Environmental Protection Agency, Seattle, WA. Windward Environmental LLC, Seattle, WA.

Zimmer, K. 2005. Personal Communication (email of November 30, 2005 to Dave Haberman, King County, Seattle, WA, concerning overflows at Emerald Services). King County, Wastewater Treatment Division, Seattle, WA.







LEGEND:

▲ Bank Samples *

▲ Surface Sediment Sample

Interpolated % Fines (Surface)

5 - 10

11 - 20

21 - 30

31 - 40

41 - 50

51 - 60

61 - 70

>70

● Outfall

□ Seep Location - May 2004 LDWG Survey

▨ Over-water Dock Structure

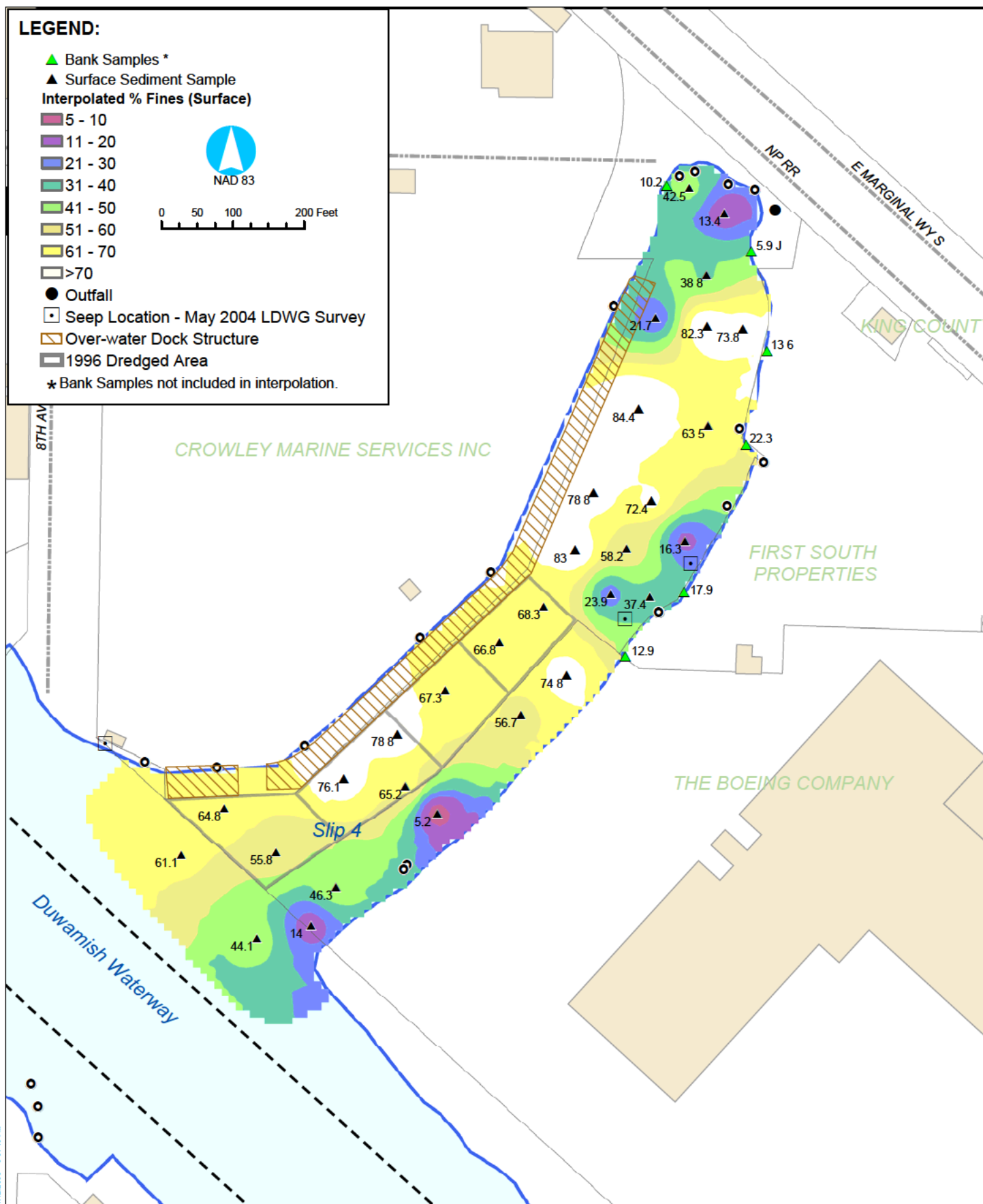
▨ 1996 Dredged Area

* Bank Samples not included in interpolation.



0 50 100 200 Feet

Map Document: (O:\Projects\Duwamish_OA\Project\Slip_4_EE\CA\Figure_2-4_Slip_4_TOC_and_FINES_Map_A4size_v2_r1.mxd)
1/12/2006 - 3:31:18 PM



integral
consulting inc.

Map Feature Sources
King County GIS, Seattle Public Utilities, USACE, Ecology,
Windward Environmental, David Evans, Inc., and others.
Sediment TOC and Fines, Lower Duwamish Project
Database 2004 slip 4 data. Percent Fine Grains queried for
surface field samples and interpolated with Inverse Distance
Weighted Method. Settings: Power of 2, 150' fixed radius search,
10 foot cell size. Field splits and replicates were not used
in the interpolation.

Qualifiers:
J = Estimated

Figure 2-4
Slip 4 - EE/CA
Distribution of Percent Fines
in Surface Sediments in 2004

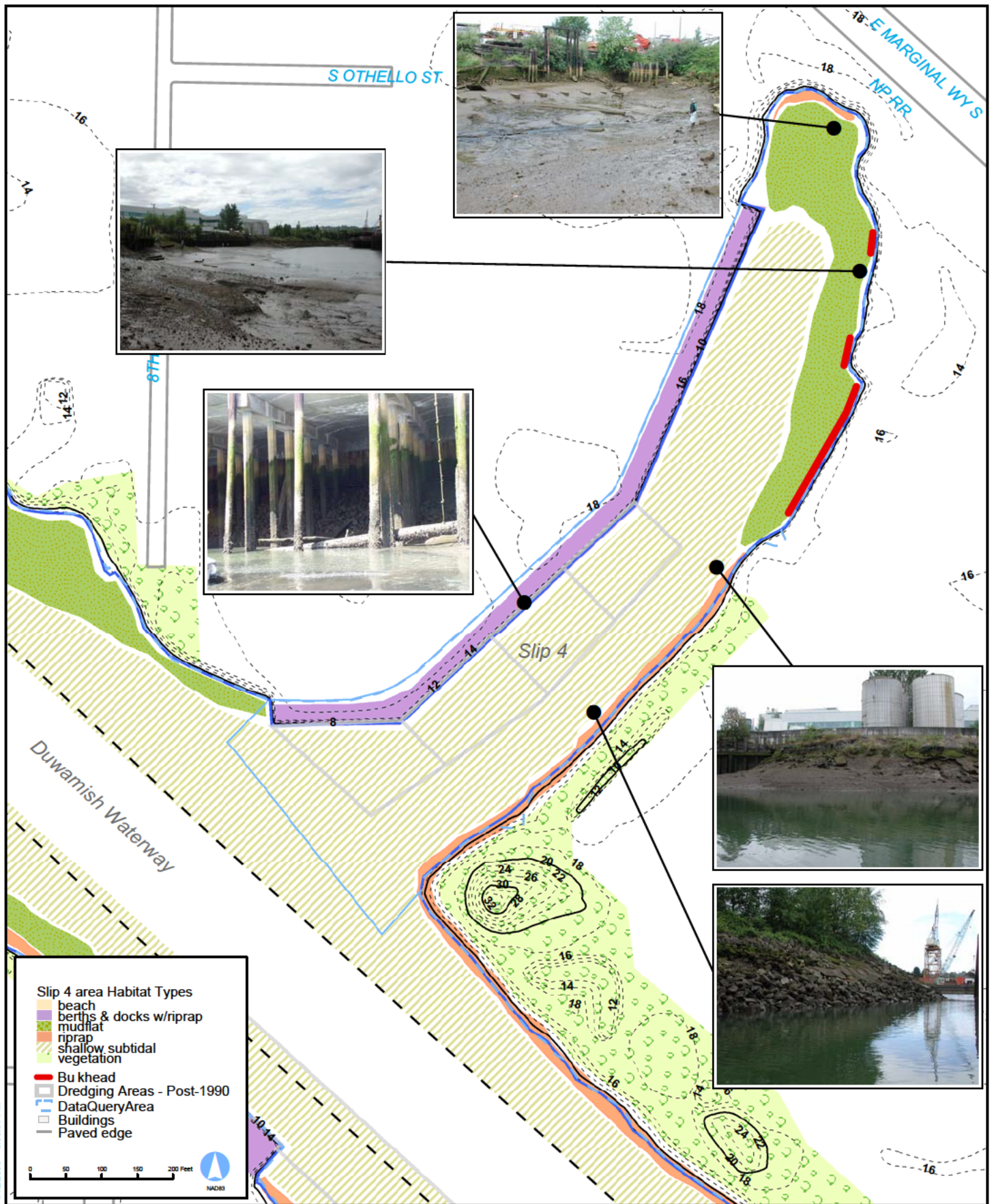
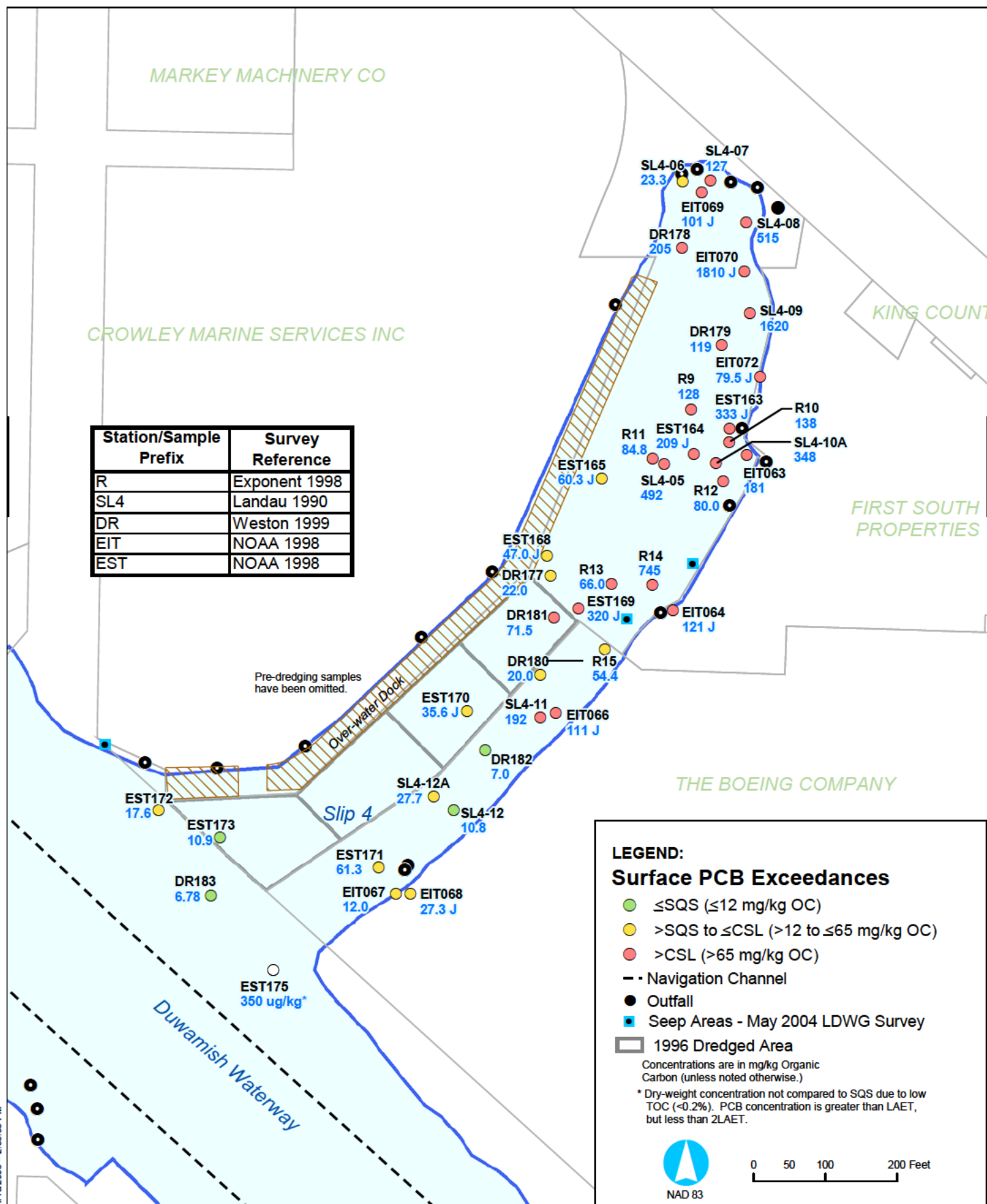


Figure 2-5
Slip 4 - EE/CA
Habitat Types

Map Document: (O:\Projects\Duwamish\OLY\Projects\Slip4_EECA\Figure_2-6_Slip4_2004_PCB_Historic_Surface_Map_Asize.mxd)
1/13/2006 - 2:36:33 PM



Map Feature Sources
King County GIS, Seattle Public Utilities,
USACE, Ecology, Windward Environmental,
David Evans, Inc., and others.
Sediment Chemistry
Lower Duwamish Project Database and 2004
Slip 4 Survey PCB analysis results.

Figure 2-6
Slip 4 - EE/CA
PCB Concentrations in Surface
Sediments Collected in 1990-1998

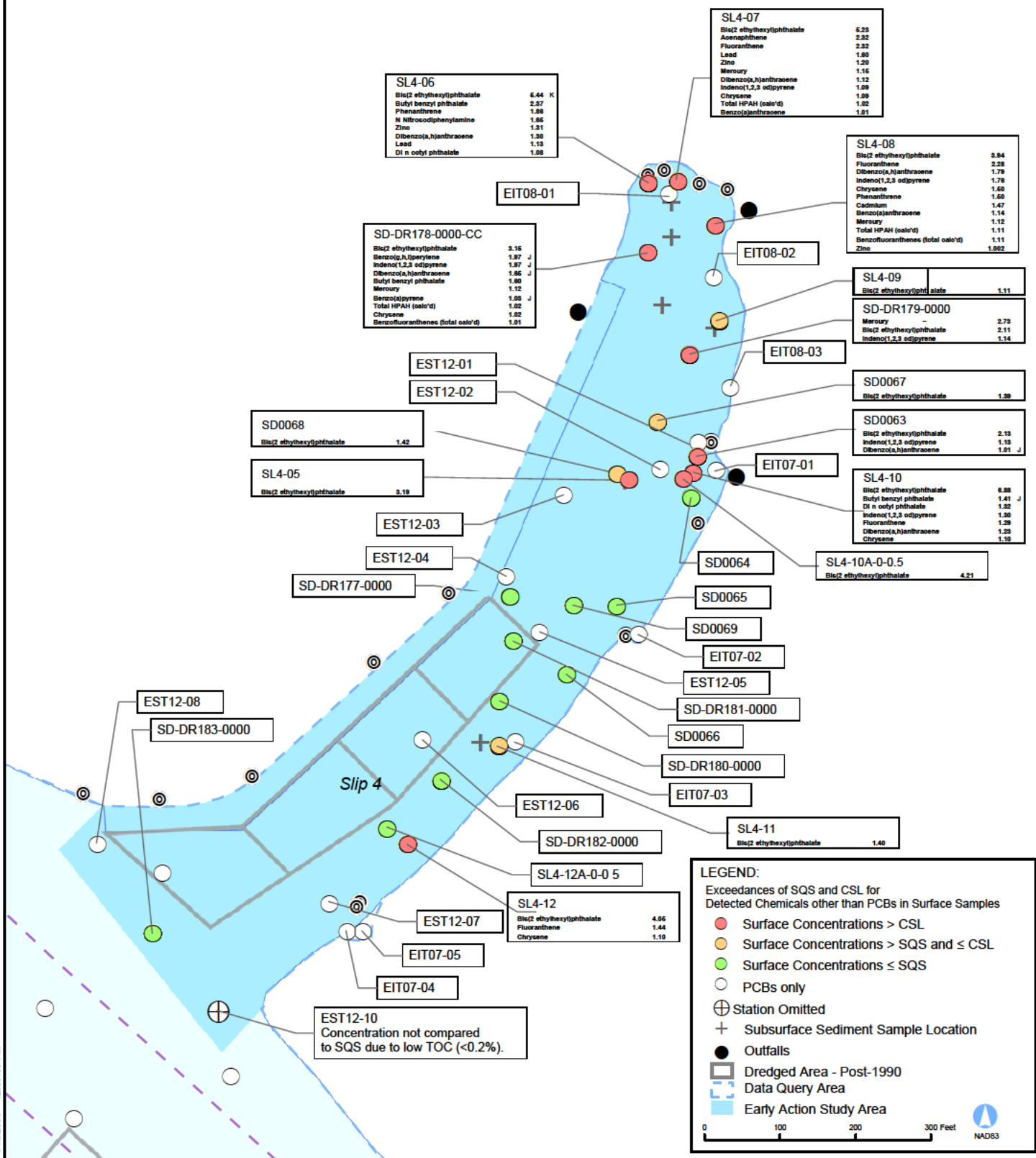
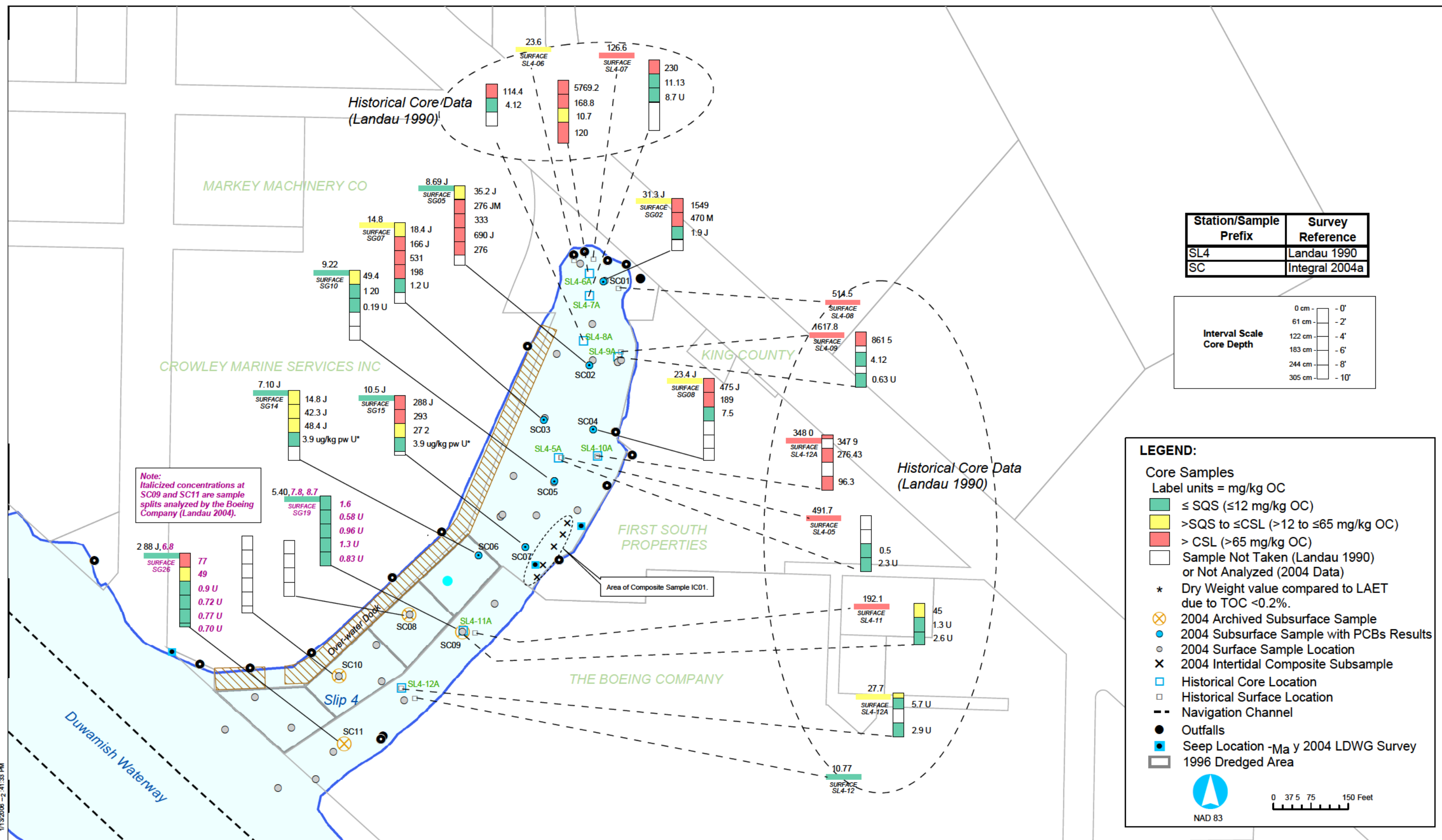
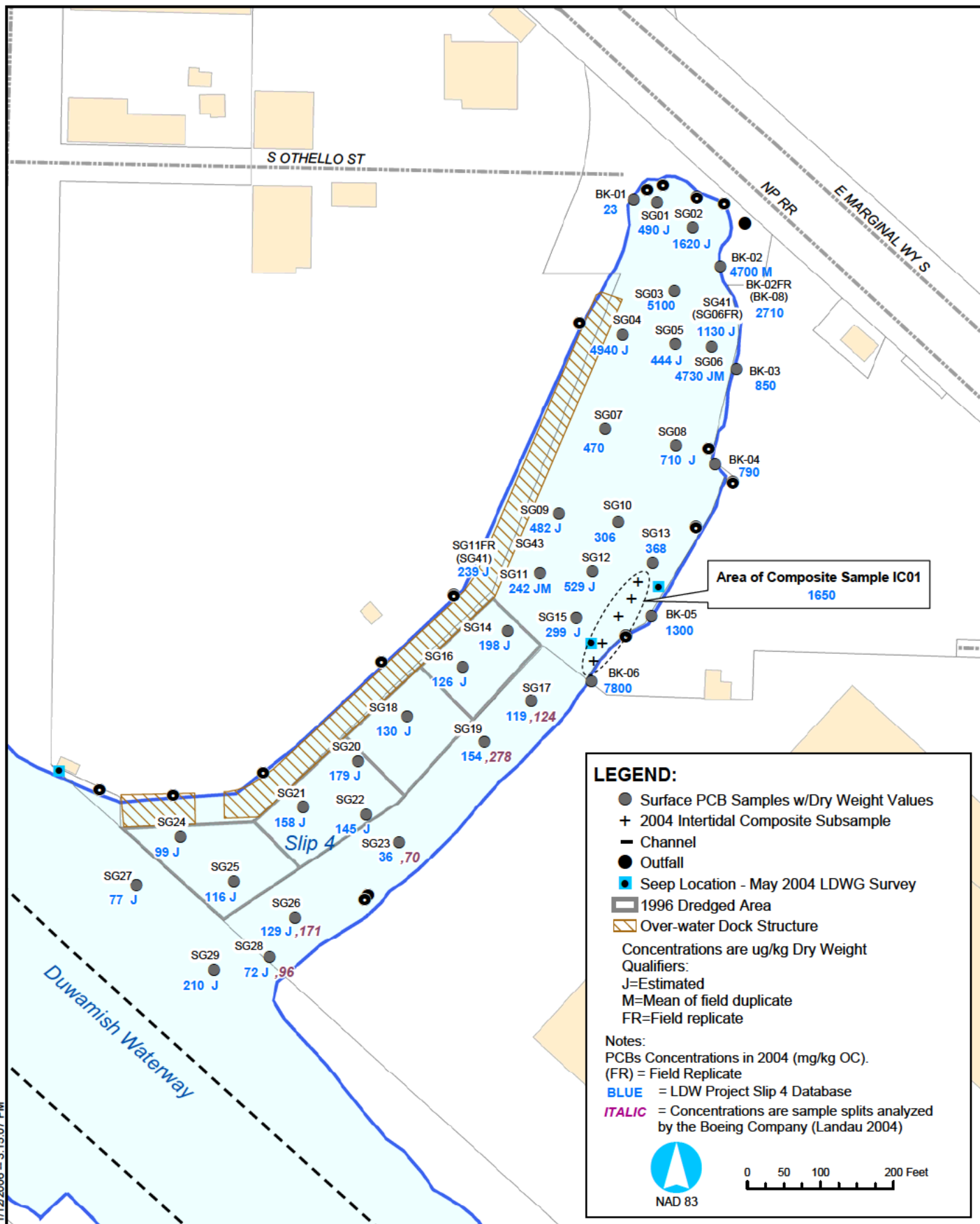
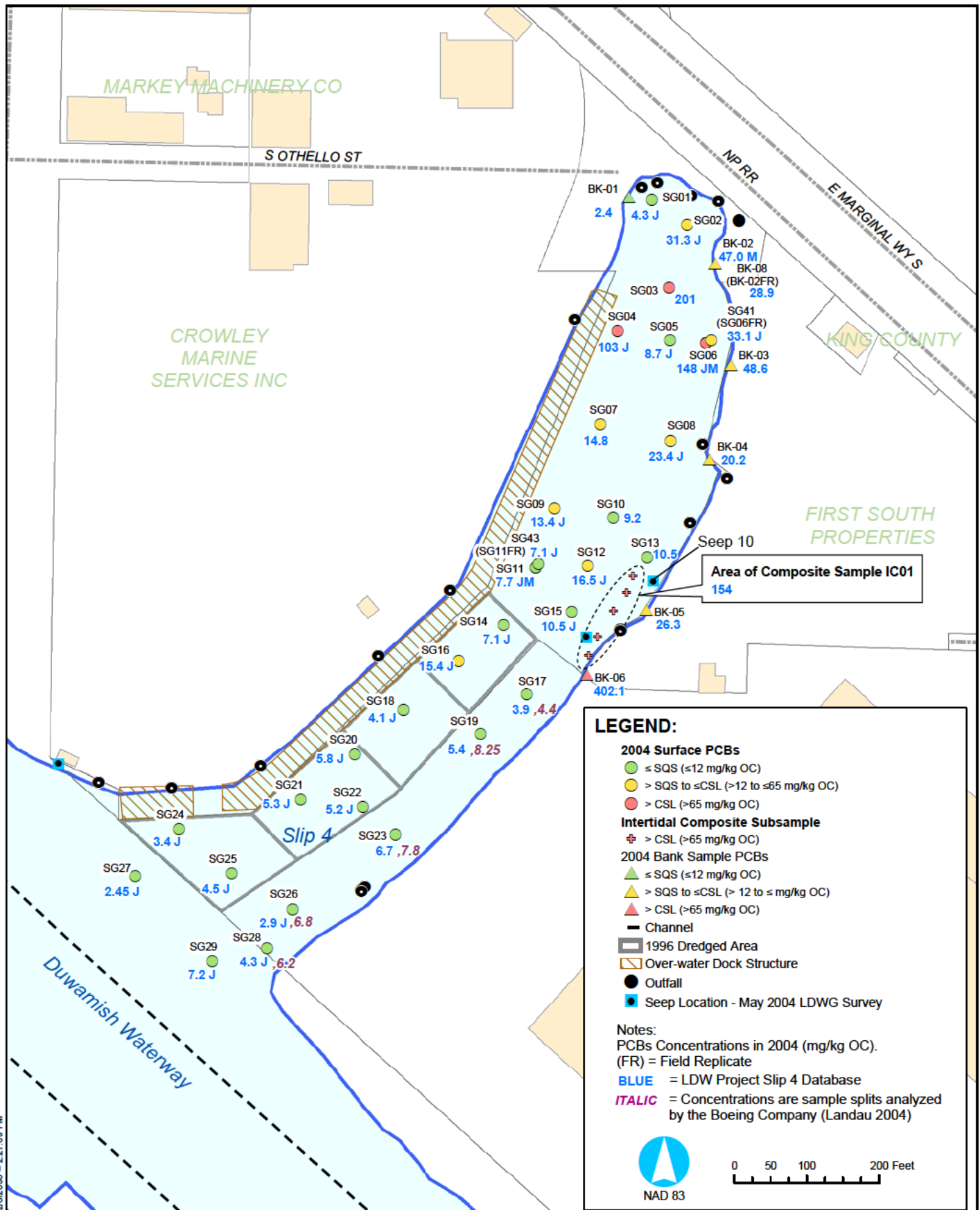


Figure 2-7
Slip 4 - EE/CA
Exceedances of SQS and CSL for
Detected Chemicals other than PCBs
in Historical Surface Sediment Samples

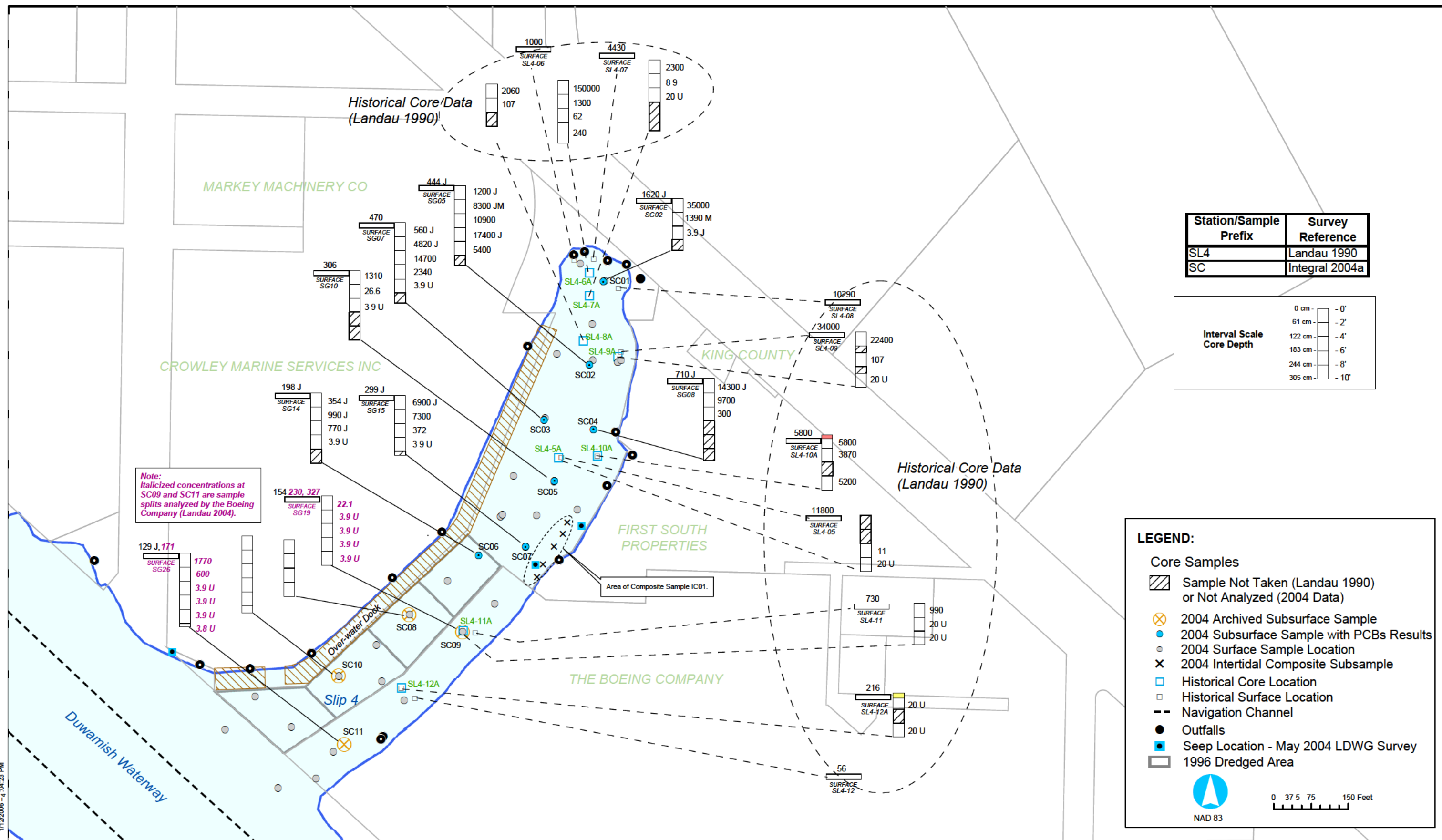


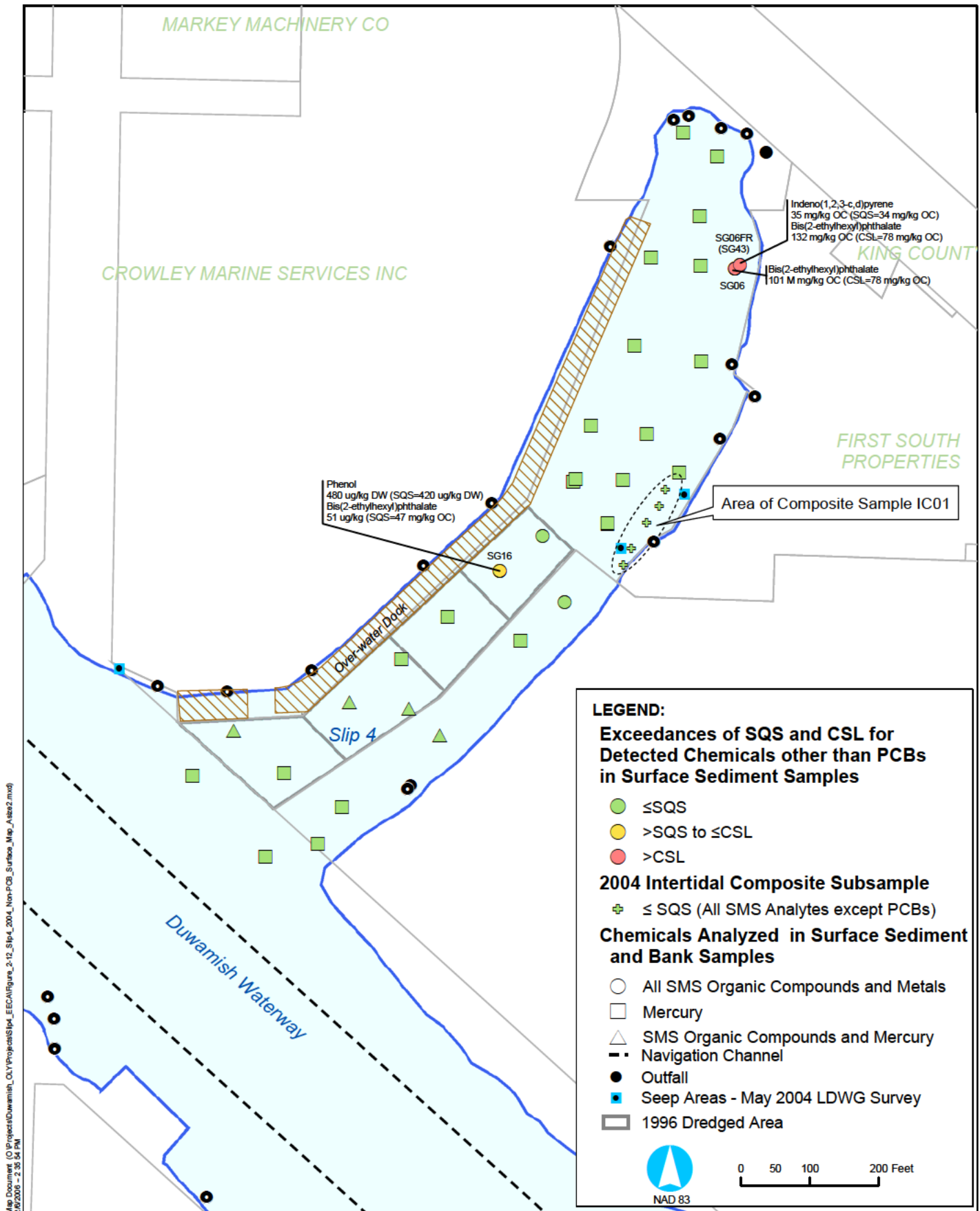


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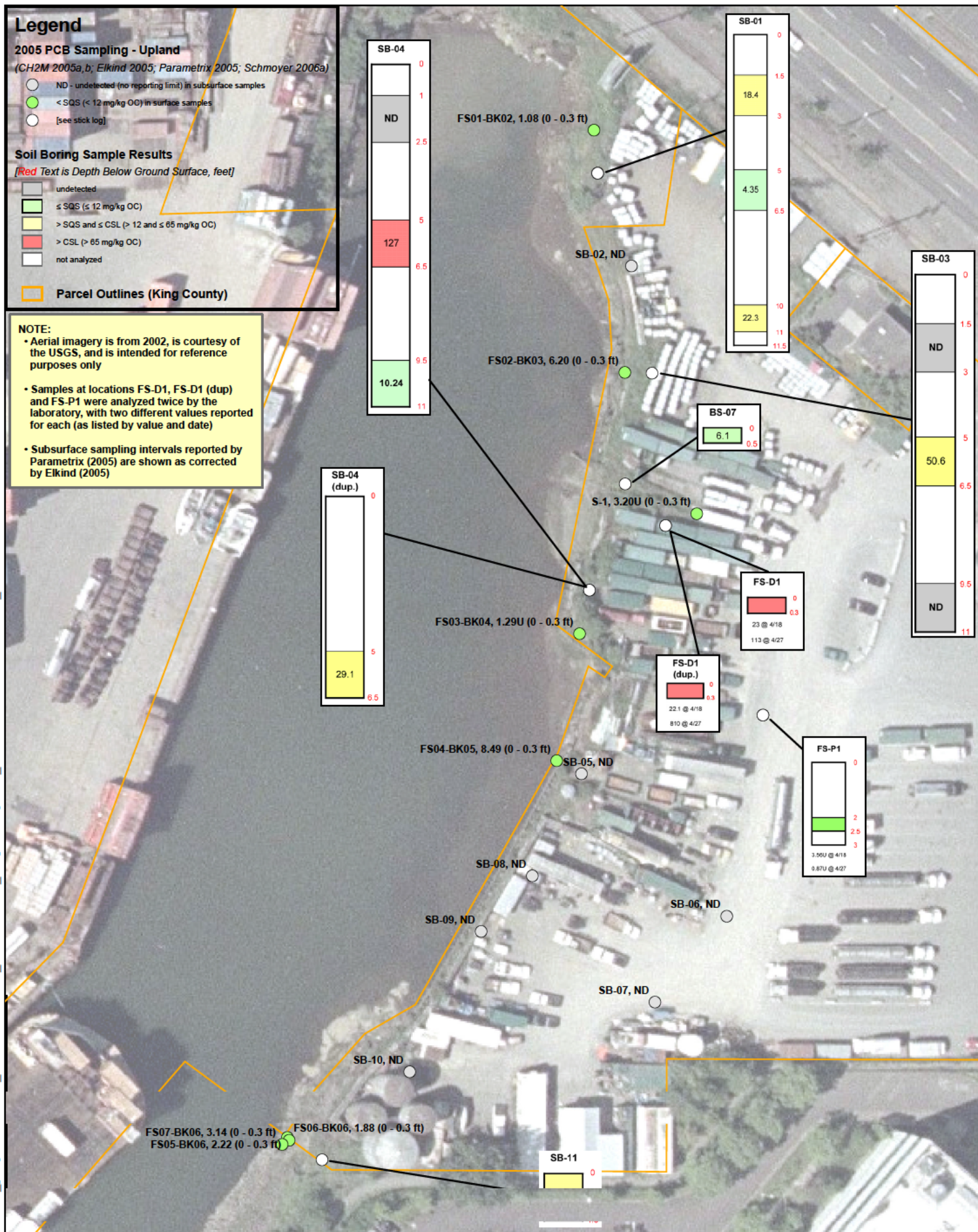


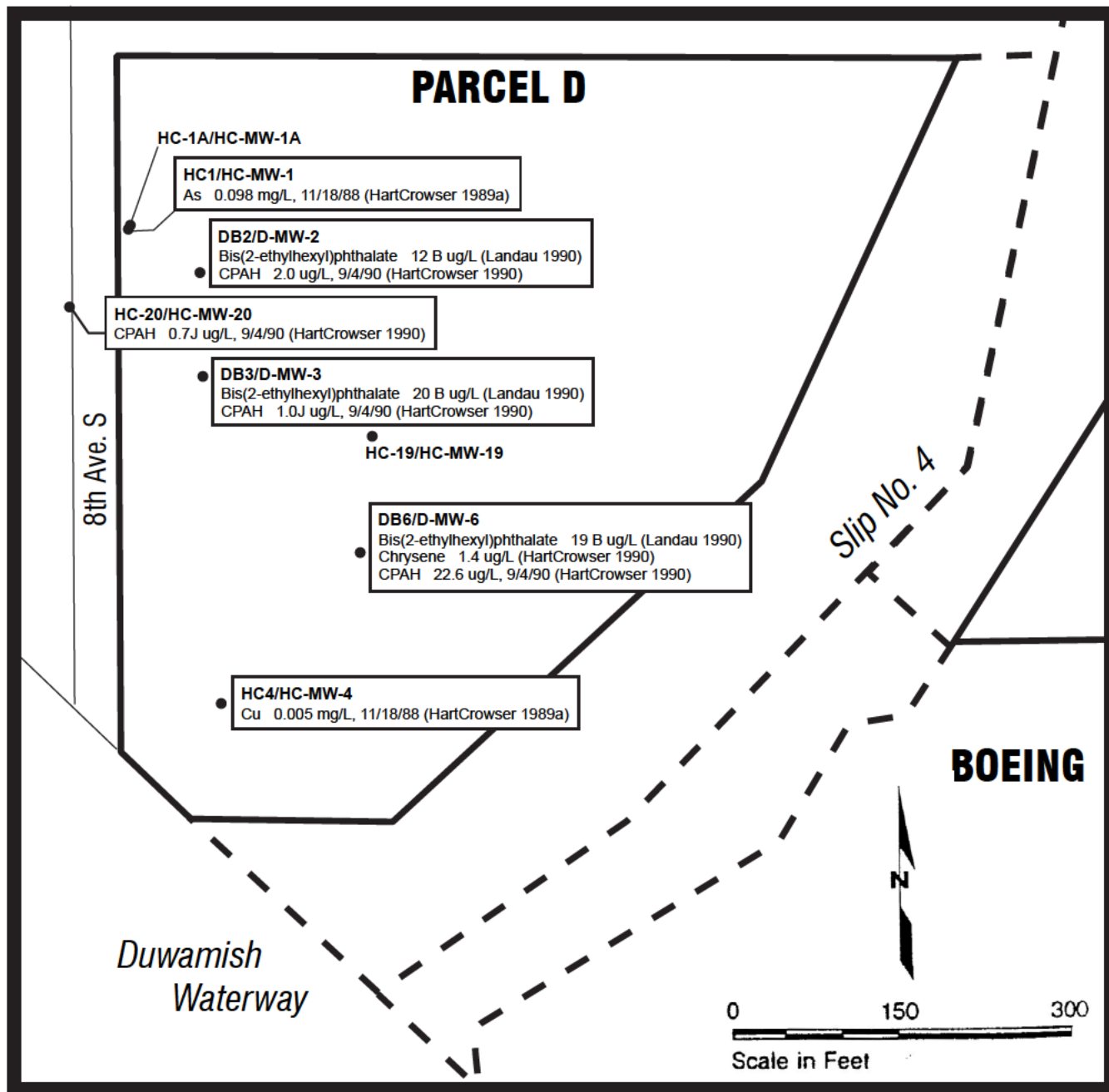
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Map Document: C:\Projects\Duwamish\SLIP_4_ECEA\Figure_2-12_Slip4_2004_Non-PCB_Surface_Map_A10x2.mxd
2/6/2006 - 2:35:54 PM





B Possible/probable blank contamination
 CPAH Sum of Carcinogenic Polyaromatic Hydrocarbons
 J Estimated Concentration

Note: NOT TO SCALE. Locations shown are approximate.

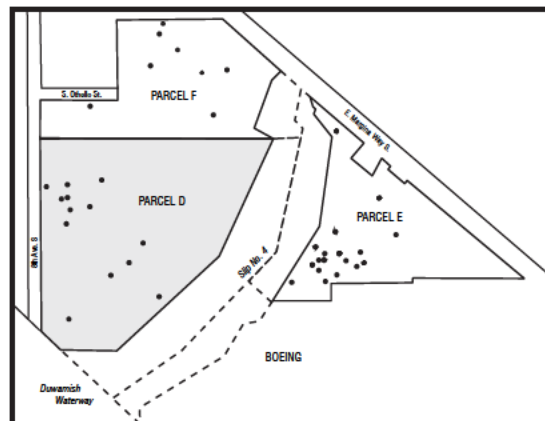


Figure 2-14. Parcel D Groundwater Exceedances of Surface Water Criteria Based on Most Recent Sampling. (modified from Hart Crowser 1990)

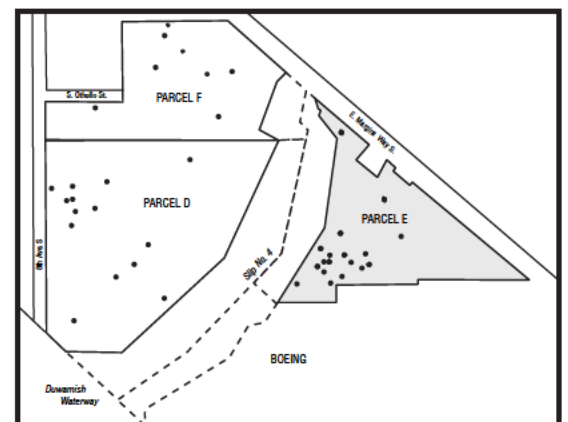
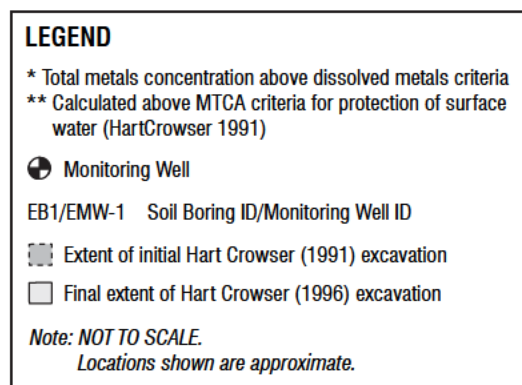
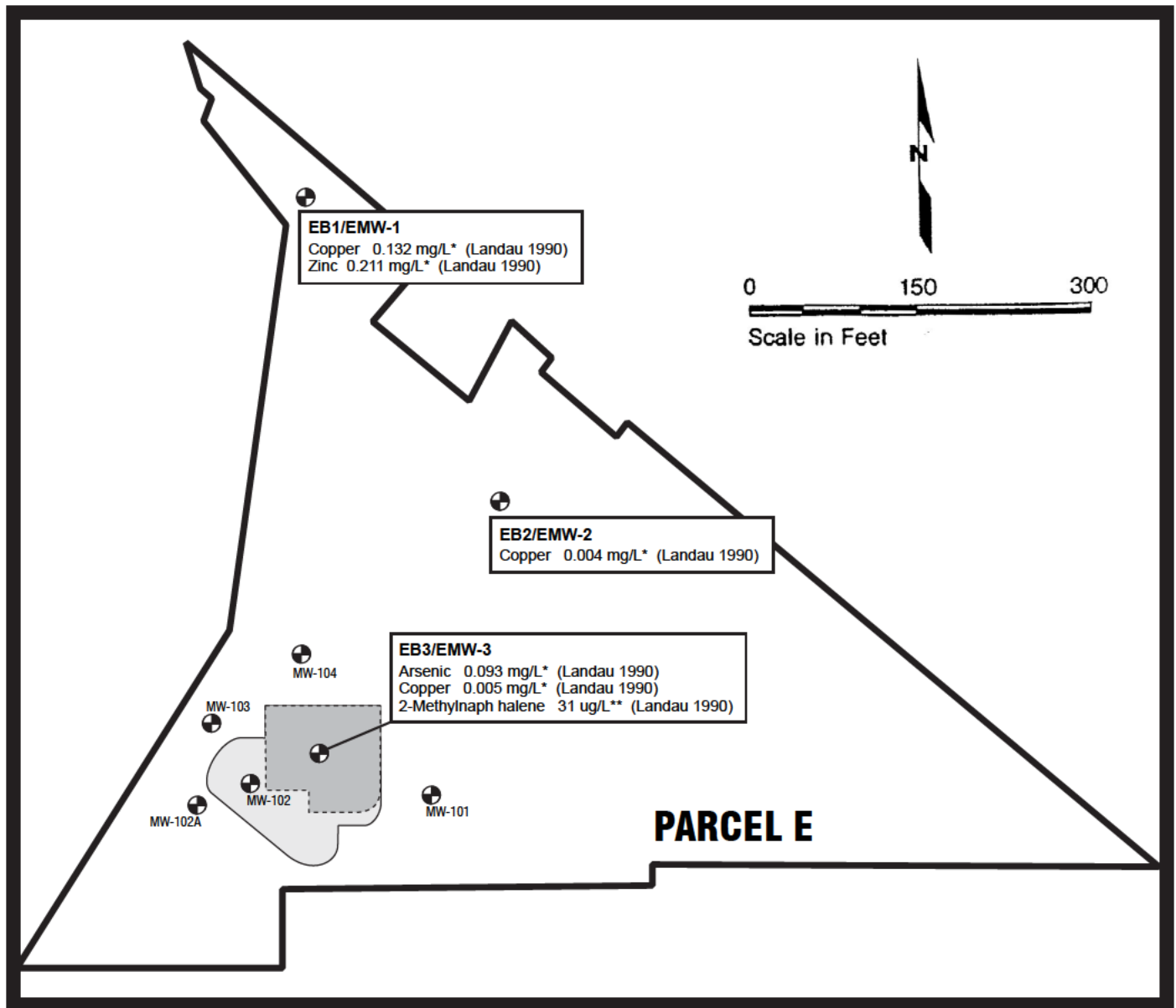
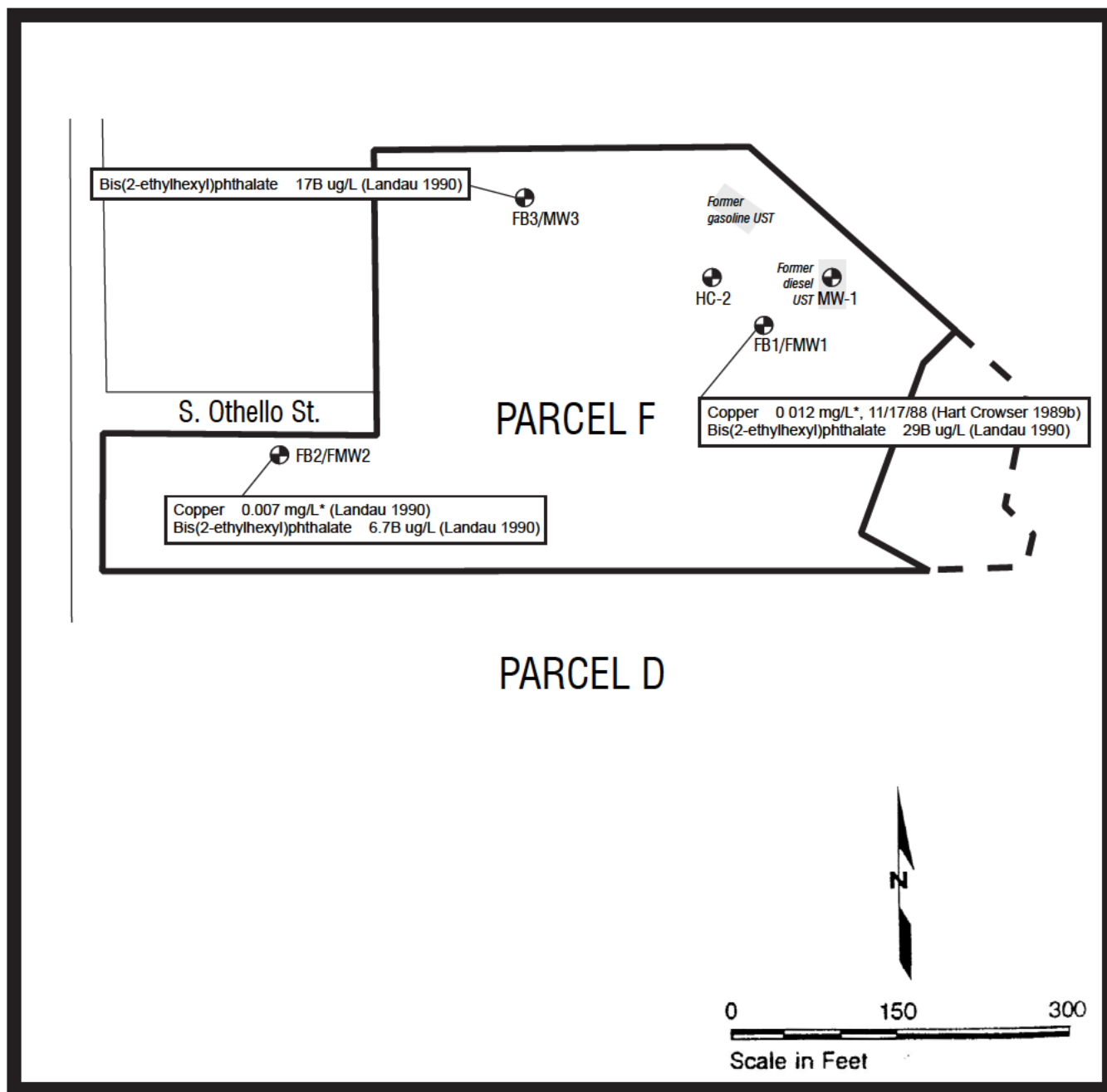


Figure 2-15. Parcel E Groundwater Exceedances of Surface Water Criteria Based on Most Recent Sampling. (Modified from Landau 1990 and Hart Crowser 1991, 1996)



LEGEND

Monitoring Well

FB1/FMW1 Soil Boring ID/Monitoring Well ID

* Total metals concentration above dissolved metal criteria

B Possible/probable blank contamination

Note: NOT TO SCALE. Locations shown are approximate.

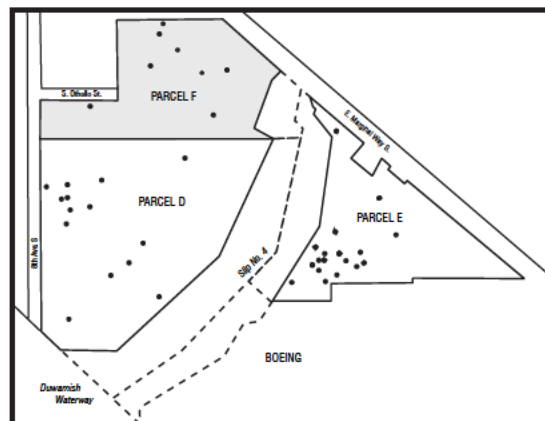


Figure 2-16. Parcel F Groundwater Exceedances of Surface Water Criteria Based on Most Recent Sampling. (modified from Hart Crowser 1989b and Landau 1990)

Legend

2005 PCB Sampling - Bank (Bach 2005a; Parametrix 2005)

- ≤ SQS (≤ 12 mg/kg OC)
- > SQS and ≤ CSL (> 12 to ≤ 65 mg/kg OC)
- > CSL (> 65 mg/kg OC)

Parcel Outlines (King County)

NOTE:

- Aerial imagery is from 2002, is courtesy of the USGS, and is intended for reference purposes only

BB-01, 65.9 (1.5 - 3 ft)
BS-01, 291 (0 - 0.5 ft)

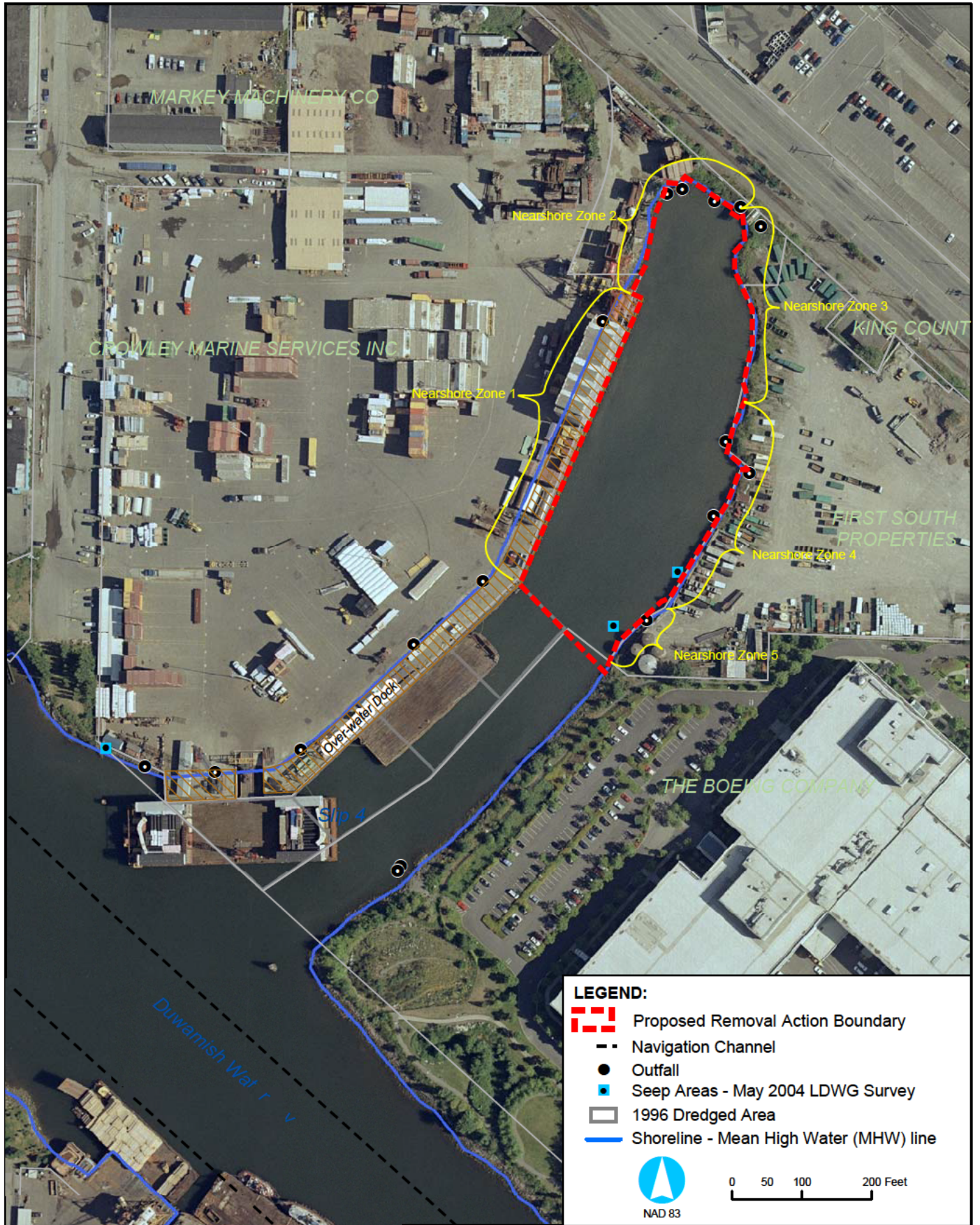
BB-02, 830 (1.5 - 3 ft)
BS-02, 60.3 (0 - 0.5 ft)

BS-03, 13.3 (0 - 0.5 ft)
BB-03, 7.85 (1.5 - 3 ft)

BB-04, 104 (1.5 - 3 ft)
BS-04, 44.6 (0 - 0.5 ft)

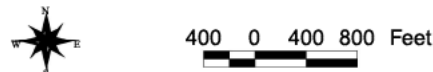
BS-05, 68.3 (0 - 0.5 ft)
BB-05, 5.82 (1.5 - 3 ft)

BS-06, 53.4 (0 - 0.5 ft)
BK-06B, 5.40 (0 - 0.3 ft)
BK-06A, 16.7 (0 - 0.3 ft)

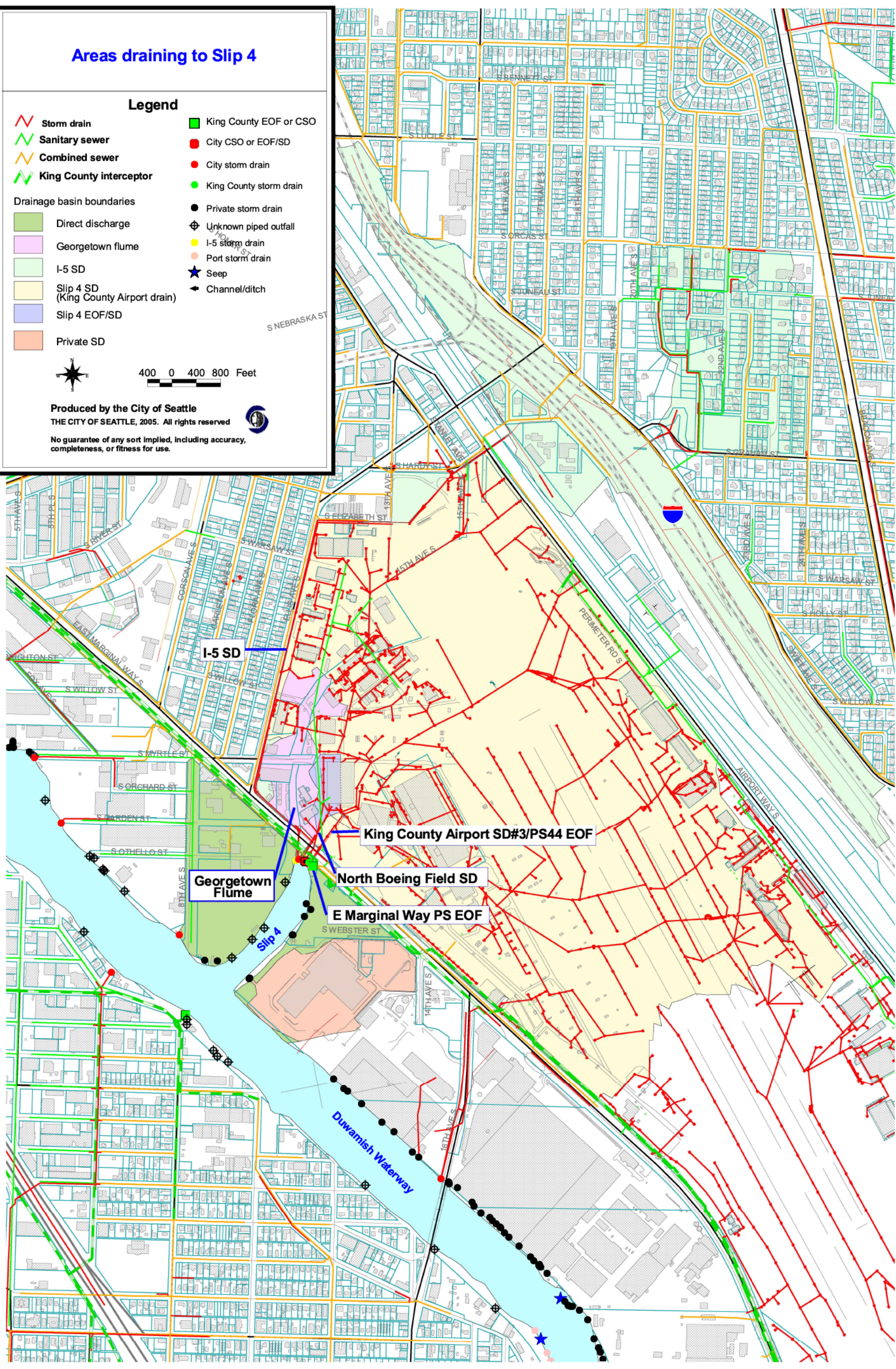


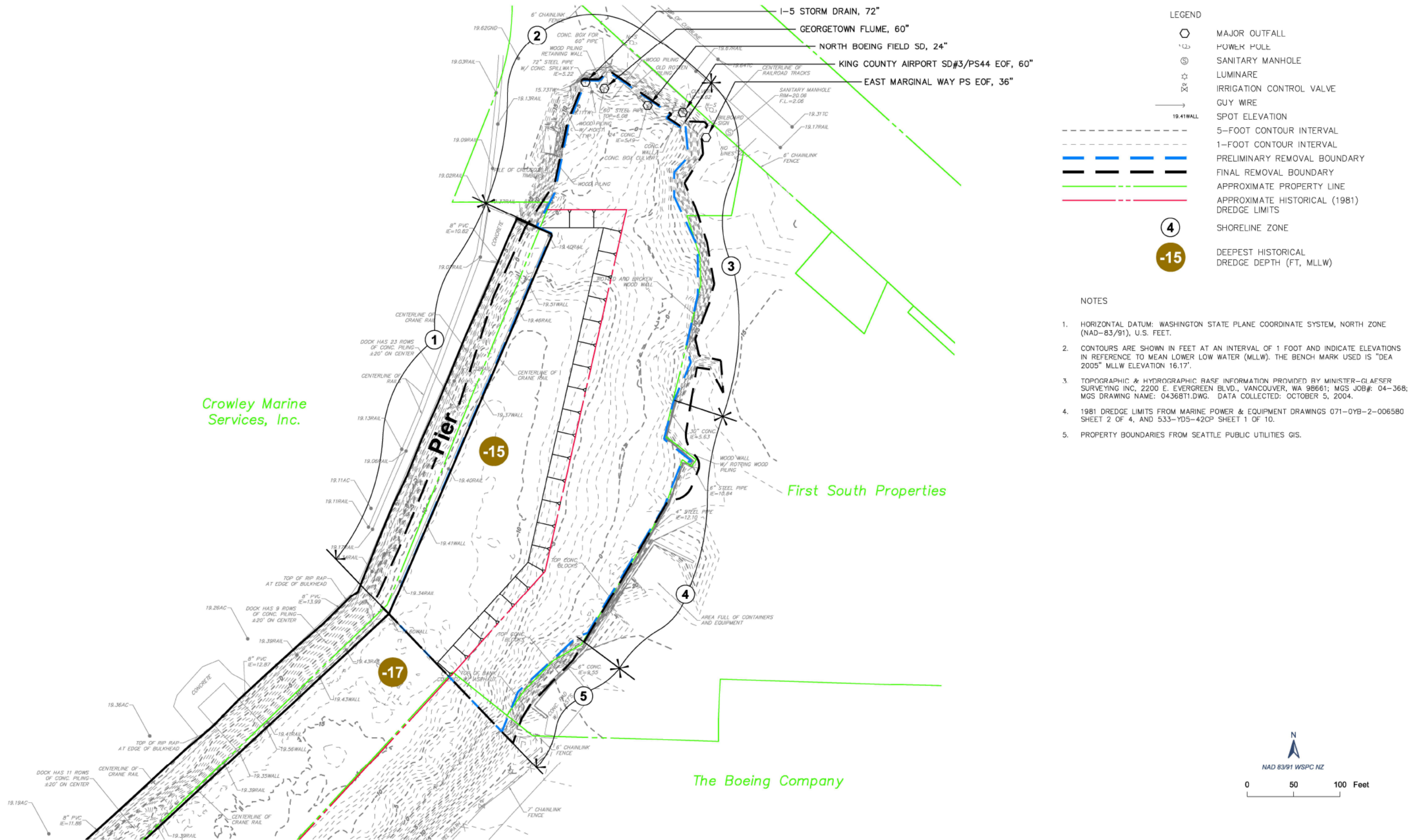
Areas draining to Slip 4

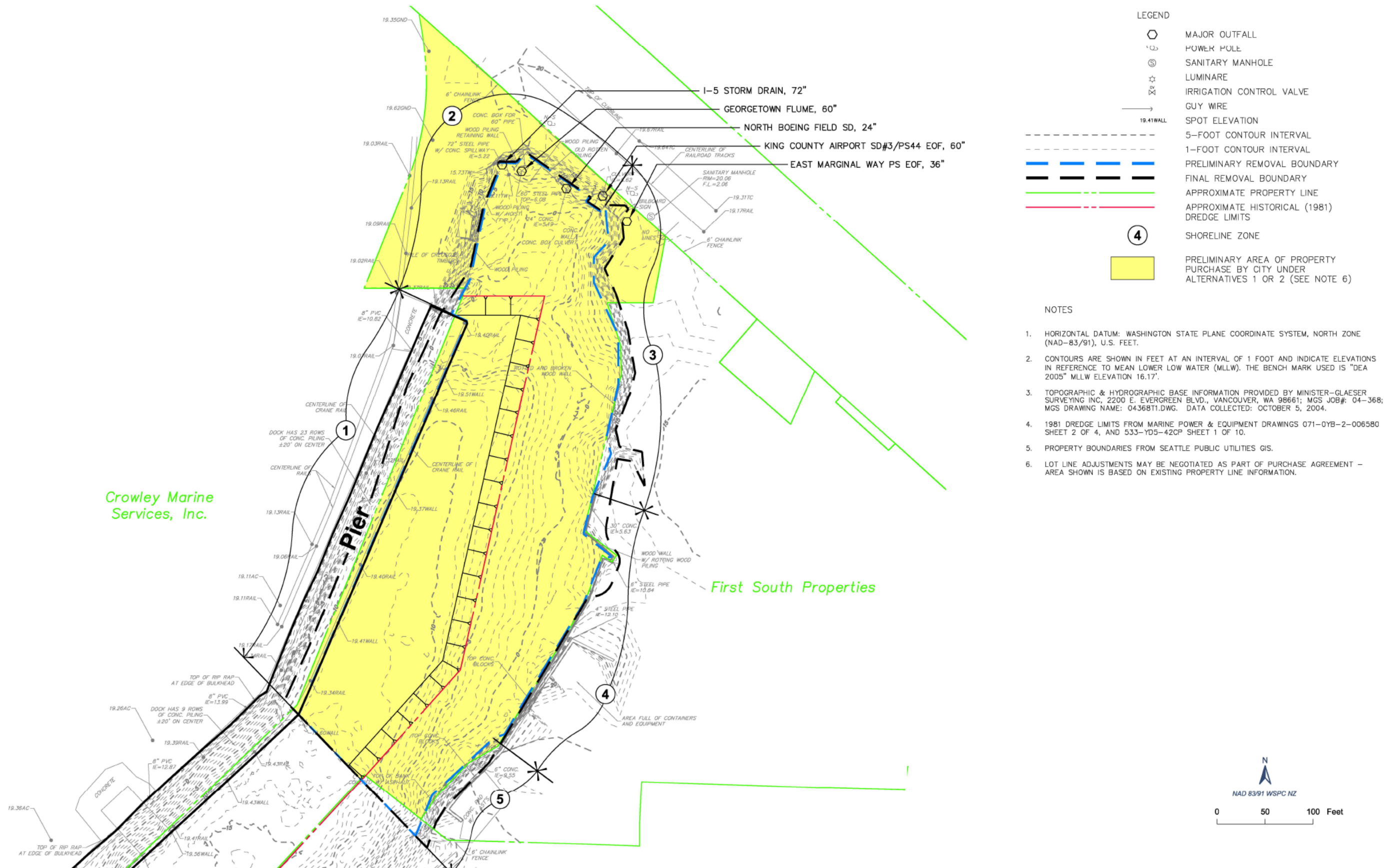
- Legend**
- Storm drain
 - Sanitary sewer
 - Combined sewer
 - King County interceptor
 - King County EOF or CSO
 - City CSO or EOF/SD
 - City storm drain
 - King County storm drain
 - Private storm drain
 - Unknown piped outfall
 - I-5 storm drain
 - Port storm drain
 - Seep
 - Channel/ditch
- Drainage basin boundaries
- Direct discharge
 - Georgetown flume
 - I-5 SD
 - Slip 4 SD (King County Airport drain)
 - Slip 4 EOF/SD
 - Private SD

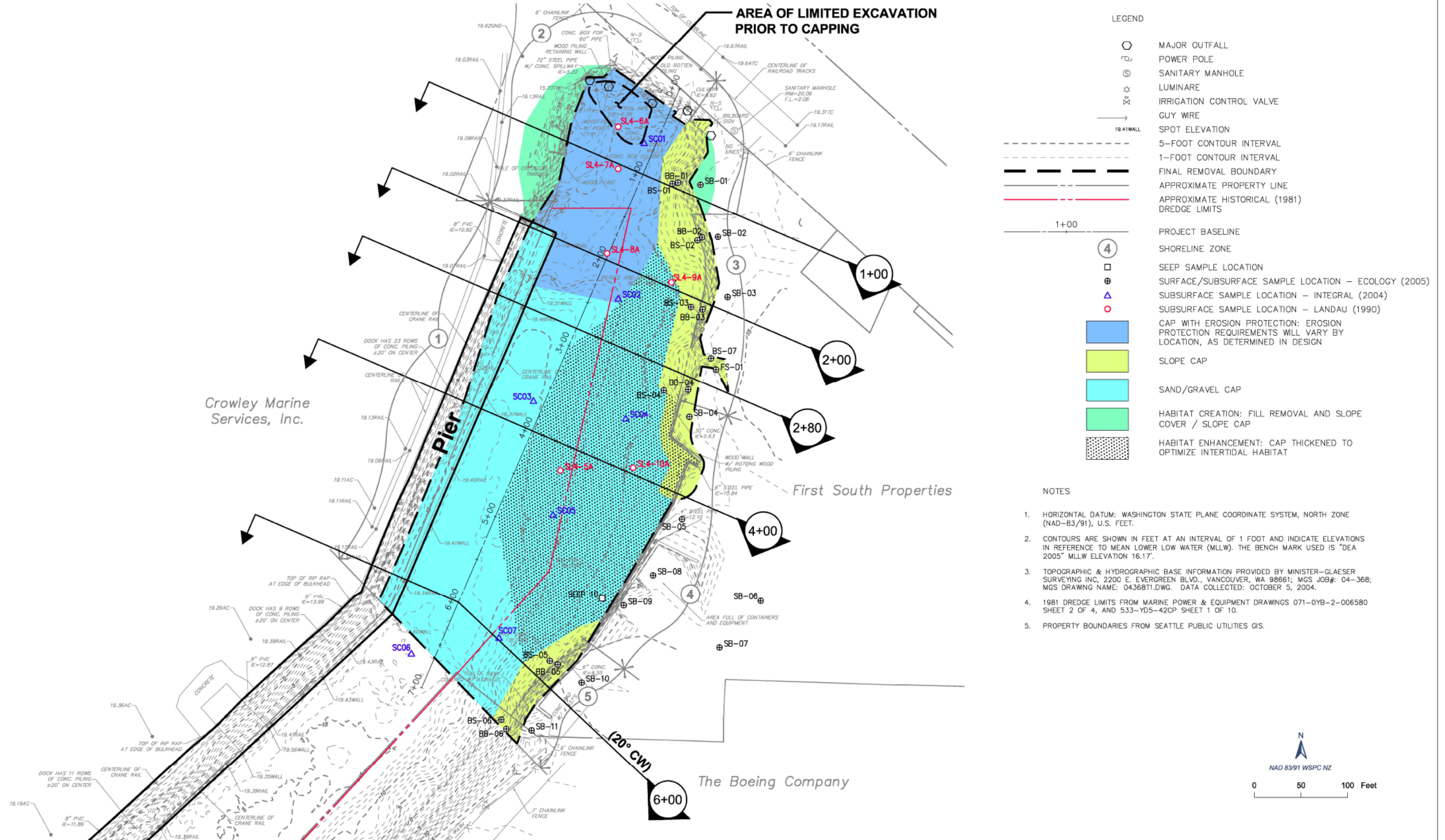


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Map Document: (FG-Cross Sections.dwg) - Layout: Alt 1 - XSEC 1+00 & 2+00
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NOTES:
1. BULKHEAD, REVETMENT, AND FENDER PILE DETAILS FROM MARINE POWER AND EQUIPMENT CO., INC. DESIGN DRAWING NO. 533-YD5-42CP. UNDER-PIER PILING NOT SHOWN. AS-BUILT CONDITIONS MAY VARY.

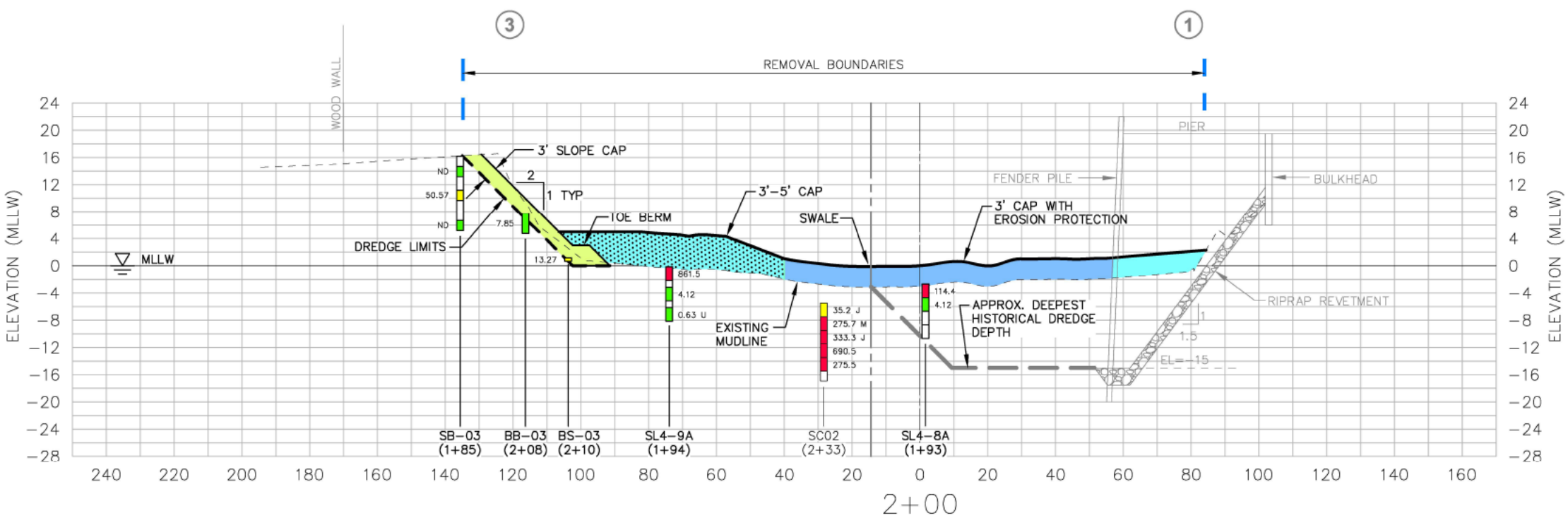
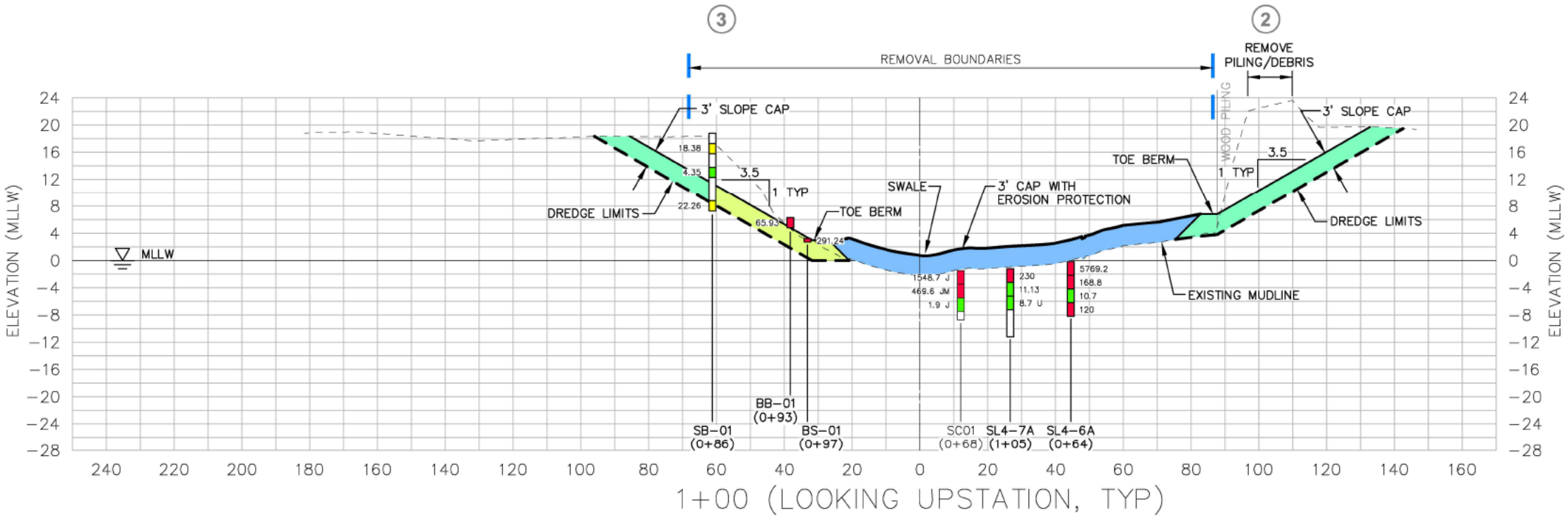
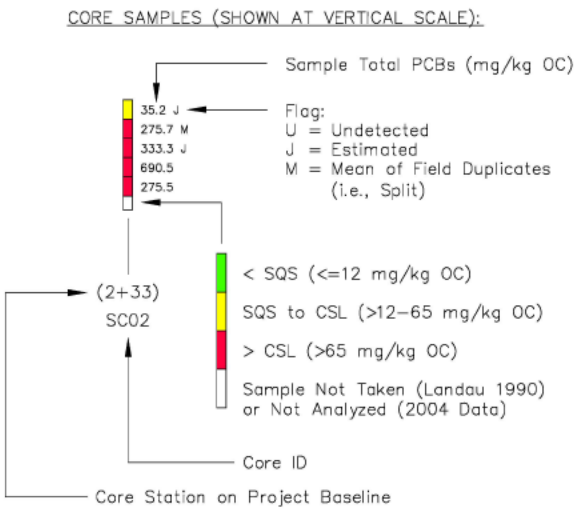
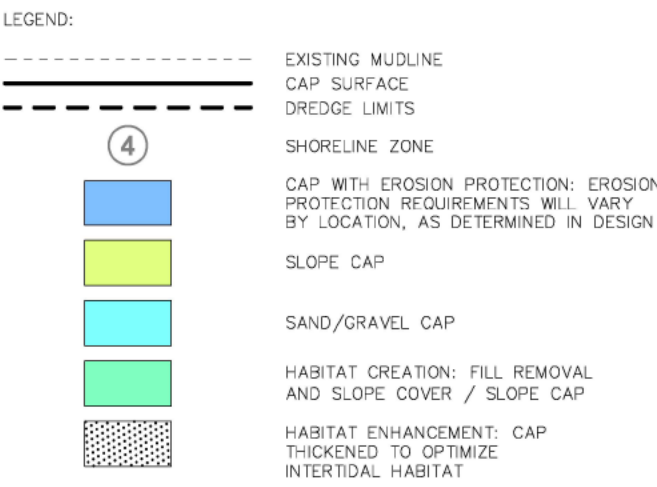


Figure 5-3
Cross Sections - Stations 1+00, 2+00
Alternative 1 - Capping and Habitat Enhancement
Slip 4 EE/CA

Map Document: (FG-Cross Sections.dwg) - Layout: Alt 1 - XSEC 2+80 & 4+00
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NOTES:
1. BULKHEAD, REVETMENT, AND FENDER PILE DETAILS FROM MARINE POWER AND EQUIPMENT CO., INC. DESIGN DRAWING NO. 533-YD5-42CP. UNDER-PIER PILING NOT SHOWN. AS-BUILT CONDITIONS MAY VARY.

LEGEND:

- EXISTING MUDLINE
- CAP SURFACE
- DREDGE LIMITS
- SHORELINE ZONE
- CAP WITH EROSION PROTECTION: EROSION PROTECTION REQUIREMENTS WILL VARY BY LOCATION, AS DETERMINED IN DESIGN
- SLOPE CAP
- SAND/GRAVEL CAP
- HABITAT CREATION: FILL REMOVAL AND SLOPE COVER / SLOPE CAP
- HABITAT ENHANCEMENT: CAP THICKENED TO OPTIMIZE INTERTIDAL HABITAT

CORE SAMPLES (SHOWN AT VERTICAL SCALE):

Sample Total PCBs (mg/kg OC)

Flag:
U = Undetected
J = Estimated
M = Mean of Field Duplicates (i.e., Split)

< SQS (<=12 mg/kg OC)
SQS to CSL (>12-65 mg/kg OC)
> CSL (>65 mg/kg OC)

Sample Not Taken (Landau 1990) or Not Analyzed (2004 Data)

Core ID

Core Station on Project Baseline

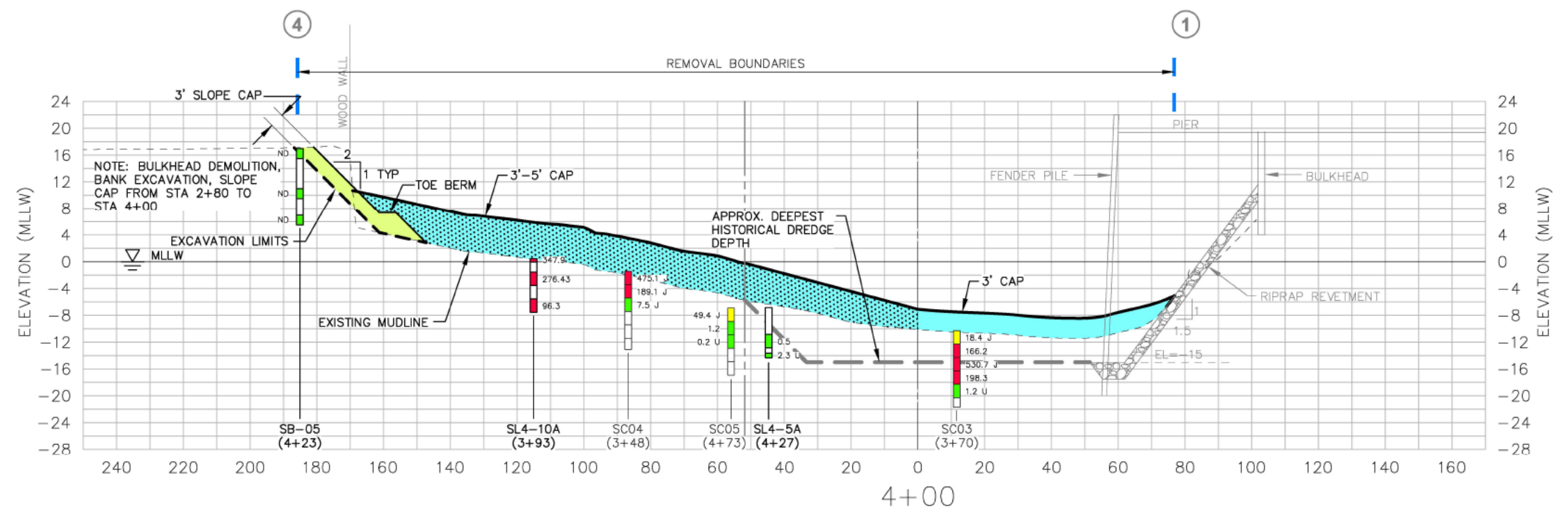
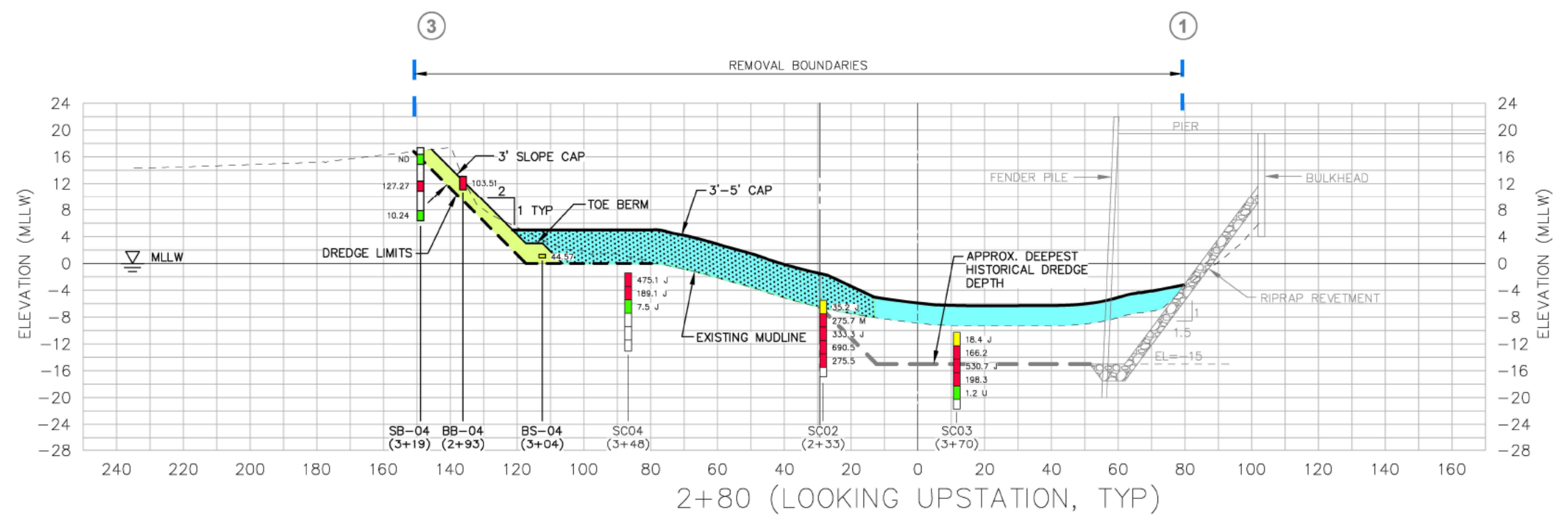
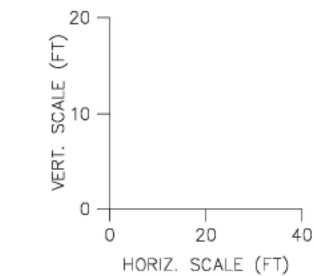


Figure 5-4
Cross Sections - Stations 2+80, 4+00
Alternative 1 - Capping and Habitat Enhancement
Slip 4 EE/CA

Map Document: (FG-Cross Sections.dwg) - Layout: Alt 1 - XSEC 6+00
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NOTES:
1. BULKHEAD, REVETMENT, AND FENDER PILE DETAILS FROM MARINE POWER AND EQUIPMENT CO., INC. DESIGN DRAWING NO. 533-YD5-42CP. UNDER-PIER PILING NOT SHOWN. AS-BUILT CONDITIONS MAY VARY.

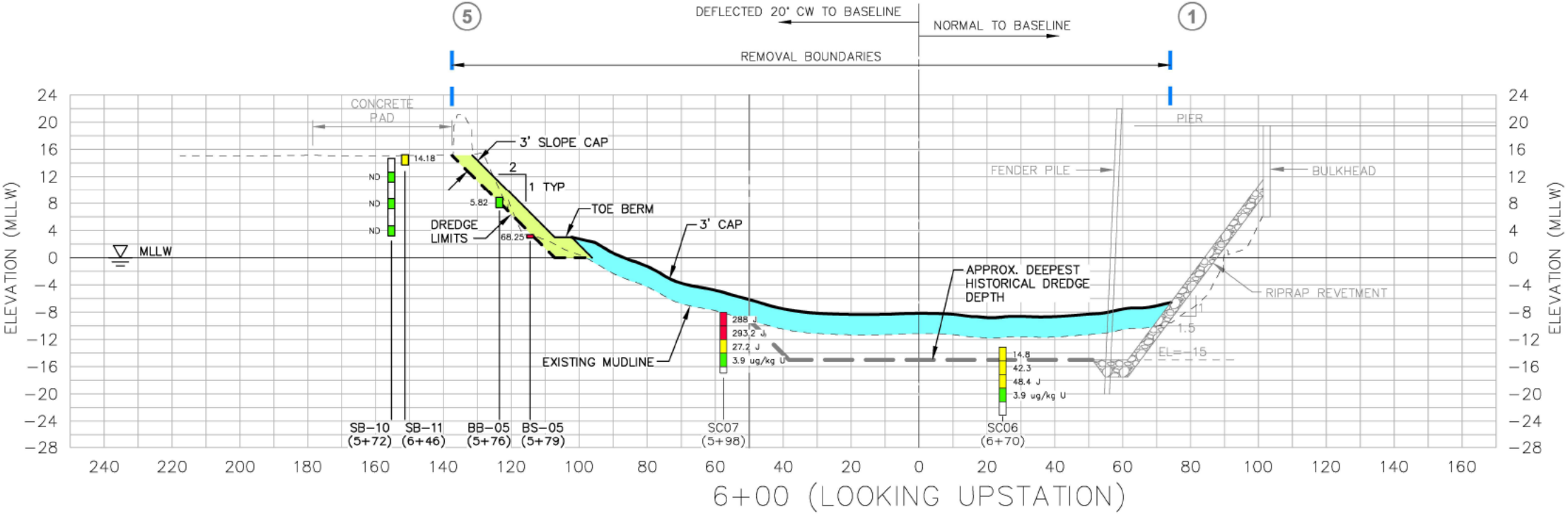
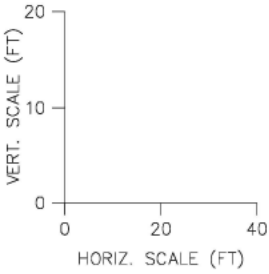
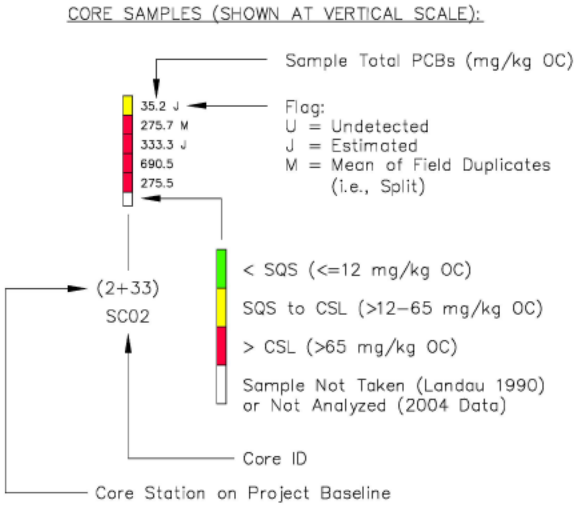
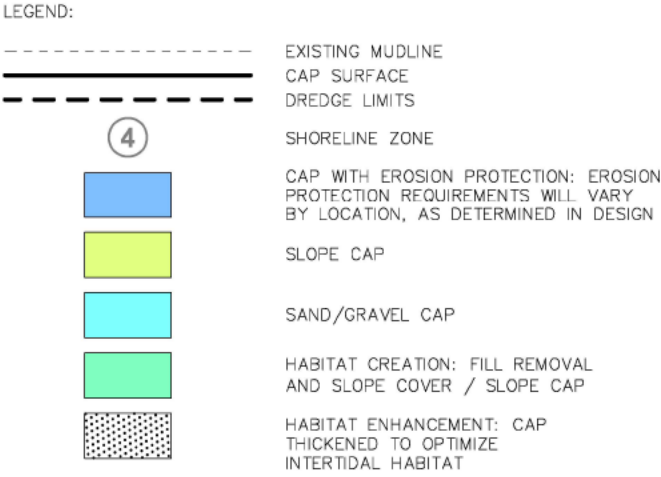




Figure 5-6
Cross Section Location Plan
Alternative 2 - Capping, Targeted Sediment Removal, and Habitat Enhancement
Slip 4 EE/CA

Map Document: (FG-Cross Sections.dwg) - Layout: Alt 2 - XSEC 1+00 & 2+00
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NOTES:
1. BULKHEAD, REVETMENT, AND FENDER PILE DETAILS FROM MARINE POWER AND EQUIPMENT CO., INC. DESIGN DRAWING NO. 533-YD5-42CP. UNDER-PIER PILING NOT SHOWN. AS-BUILT CONDITIONS MAY VARY.

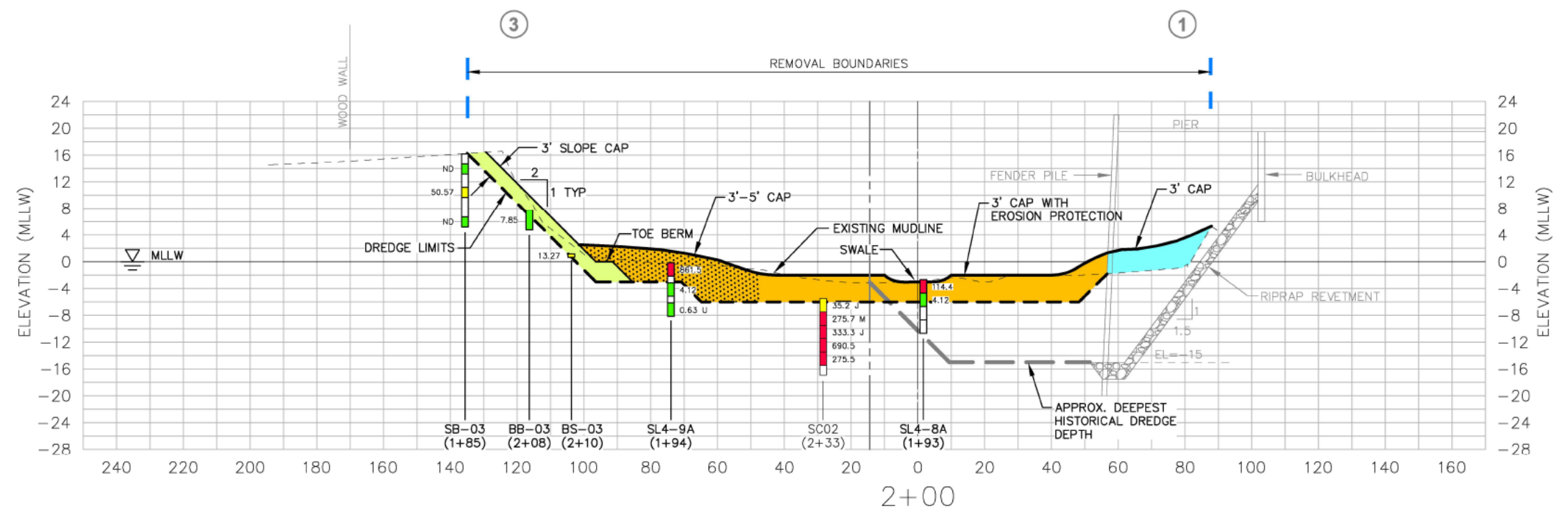
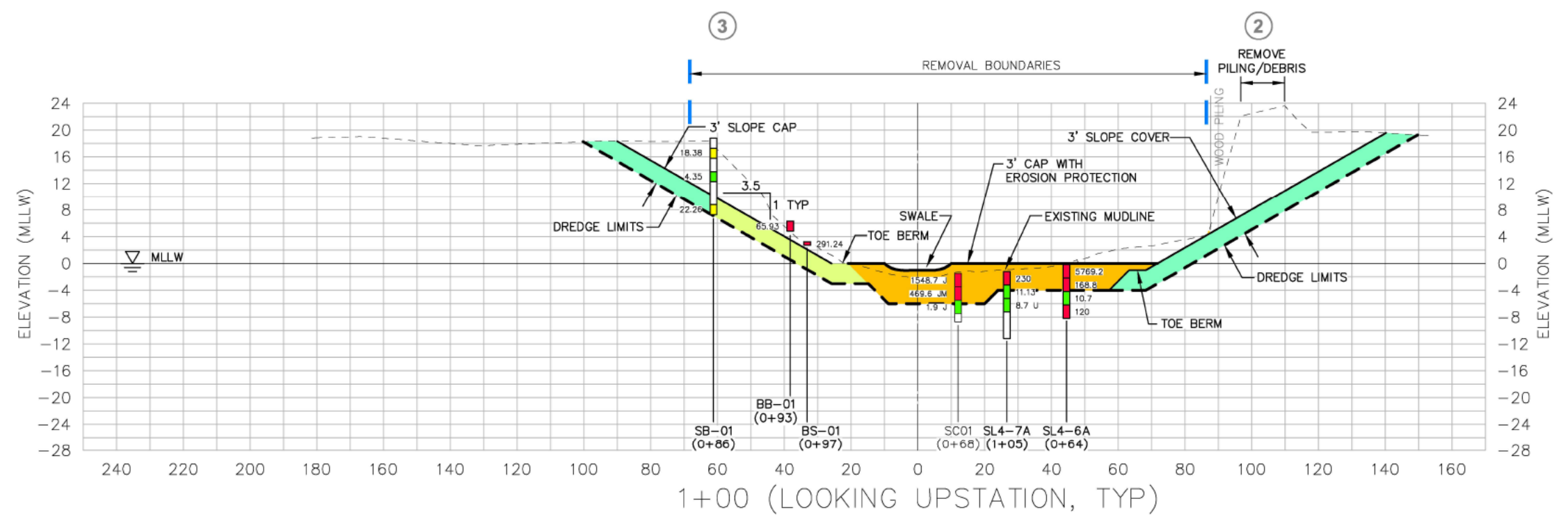
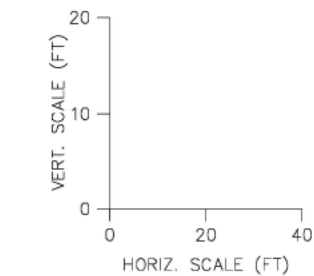
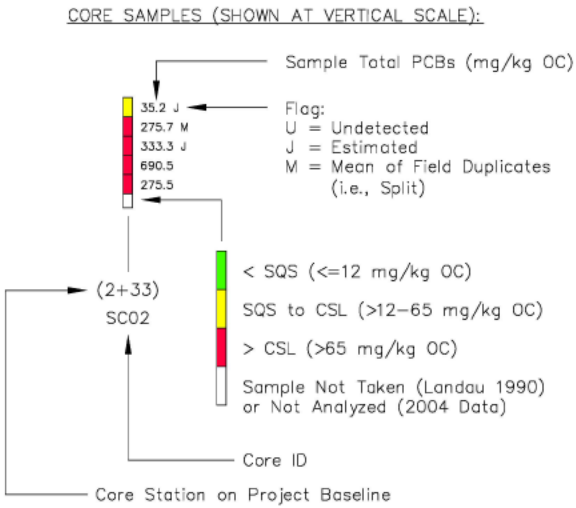
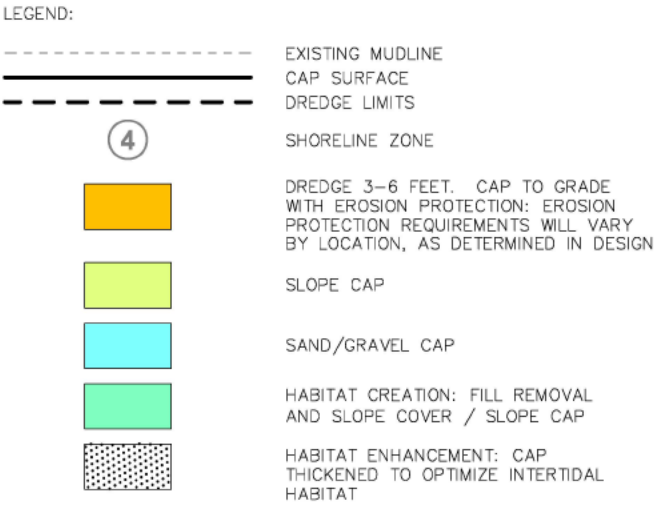


Figure 5-7
Cross Sections - Stations 1+00, 2+00
Alternative 2 - Capping, Targeted Sediment Removal, and Habitat Enhancement
Slip 4 EE/CA

Map Document: (FG-Cross Sections.dwg) - Layout: Alt 2 - XSEC 2+80 & 4+00
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NOTES:
1. BULKHEAD, REVETMENT, AND FENDER PILE DETAILS FROM MARINE POWER AND EQUIPMENT CO., INC. DESIGN DRAWING NO. 533-YD5-42CP. UNDER-PIER PILING NOT SHOWN. AS-BUILT CONDITIONS MAY VARY.

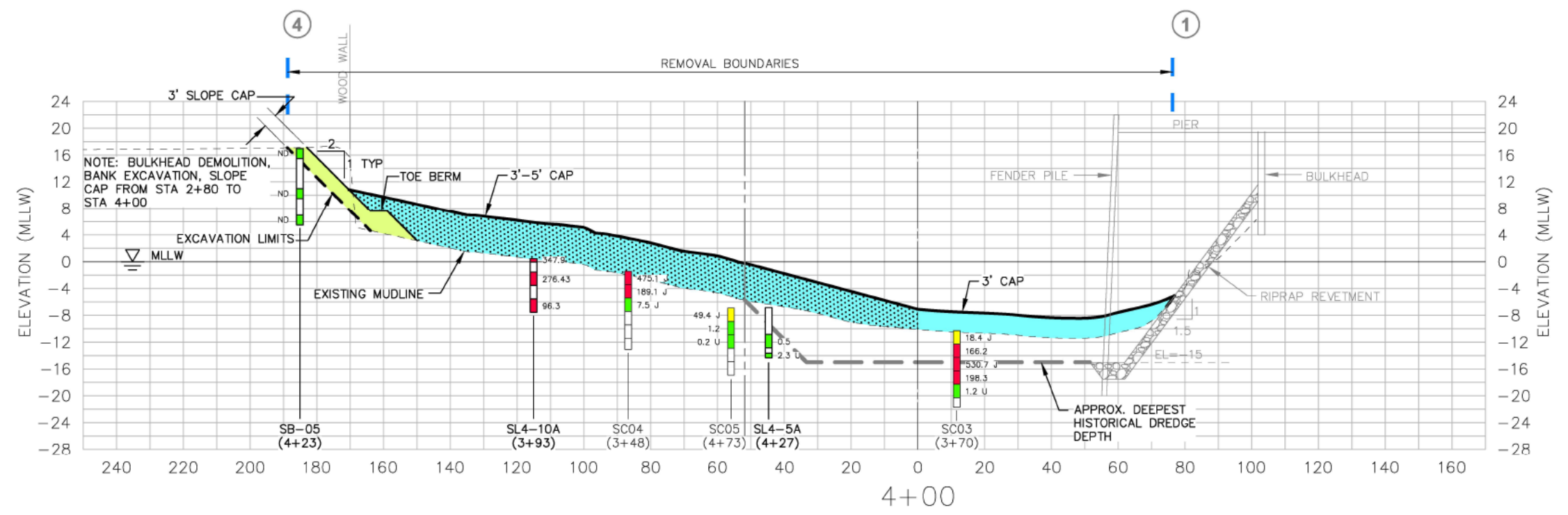
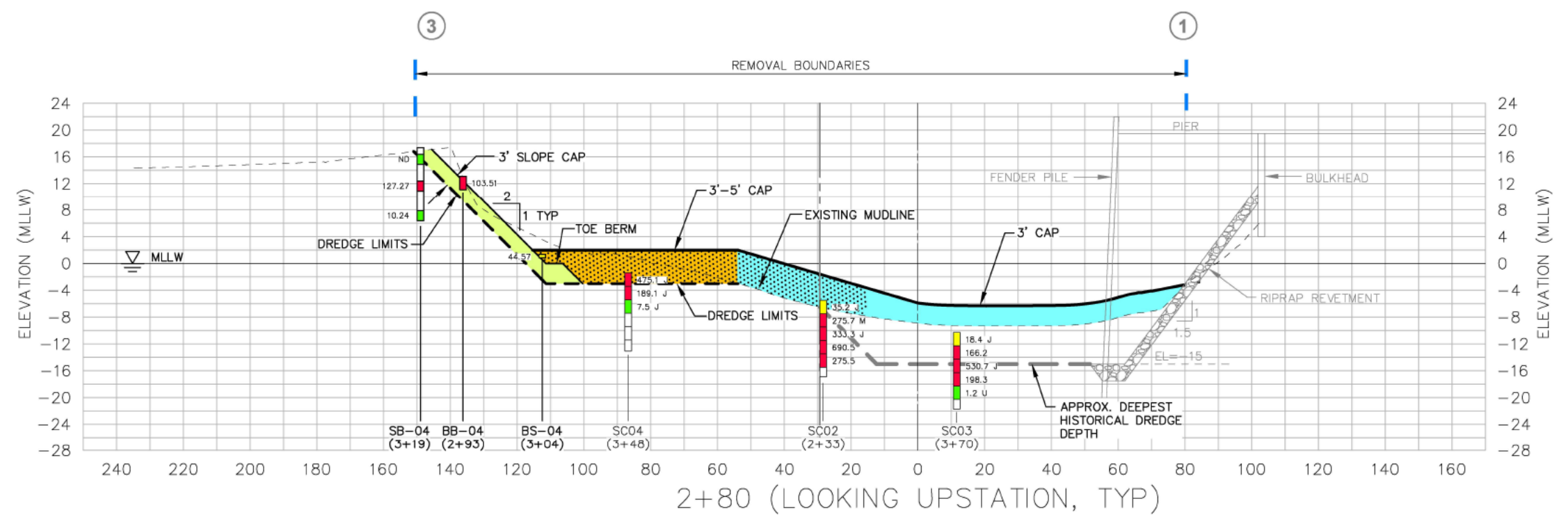
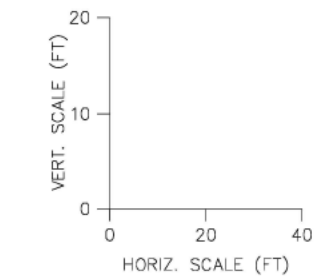
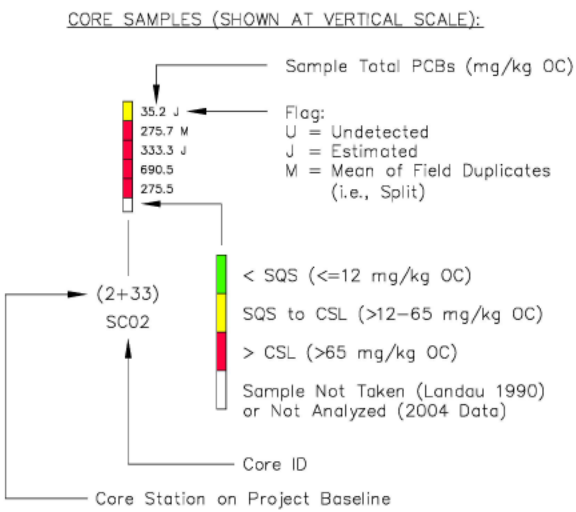
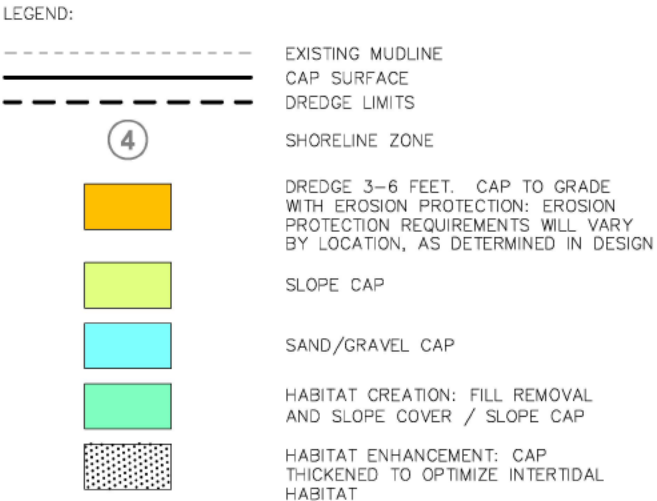


Figure 5-8
Cross Sections - Stations 2+80, 4+00
Alternative 2 - Capping, Targeted Sediment Removal, and Habitat Enhancement
Slip 4 EE/CA

Map Document: (FG-Cross Sections.dwg) - Layout: Alt 2 - XSEC 6+00
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NOTES:
1. BULKHEAD, REVETMENT, AND FENDER PILE DETAILS FROM MARINE POWER AND EQUIPMENT CO., INC. DESIGN DRAWING NO. 533-YD5-42CP. UNDER-PIER PILING NOT SHOWN. AS-BUILT CONDITIONS MAY VARY.

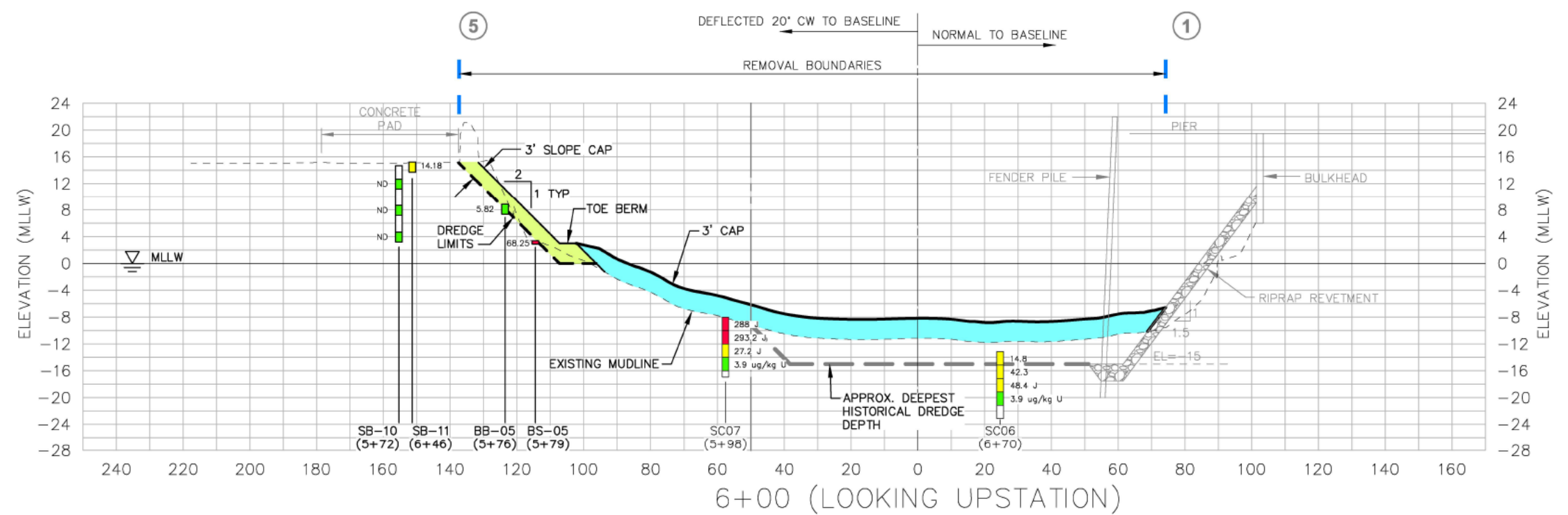
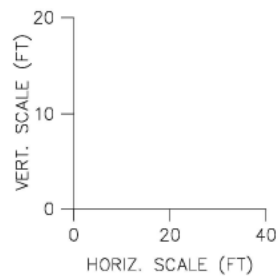
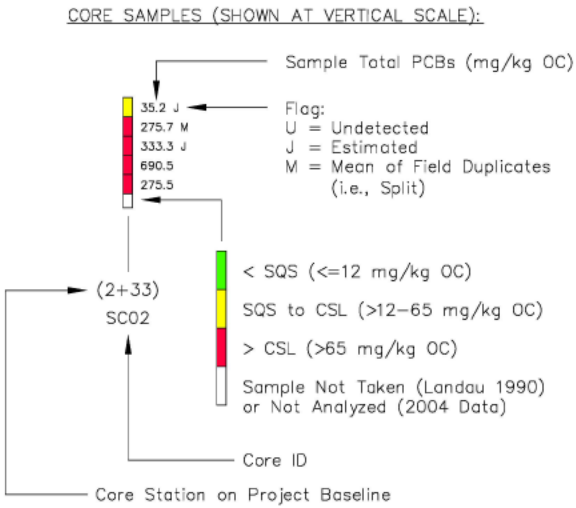
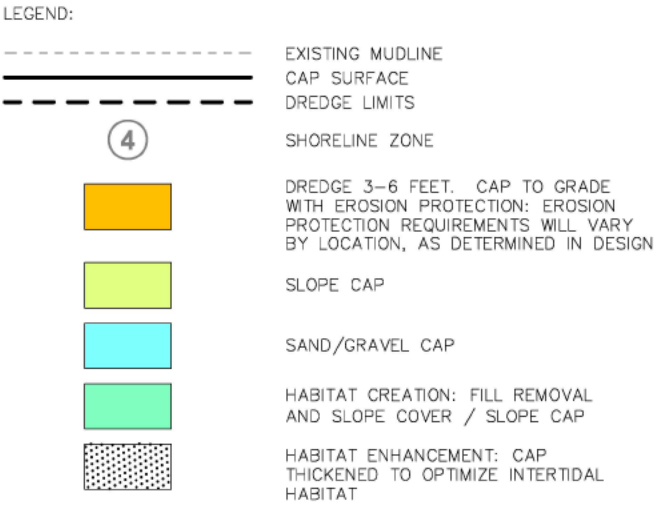
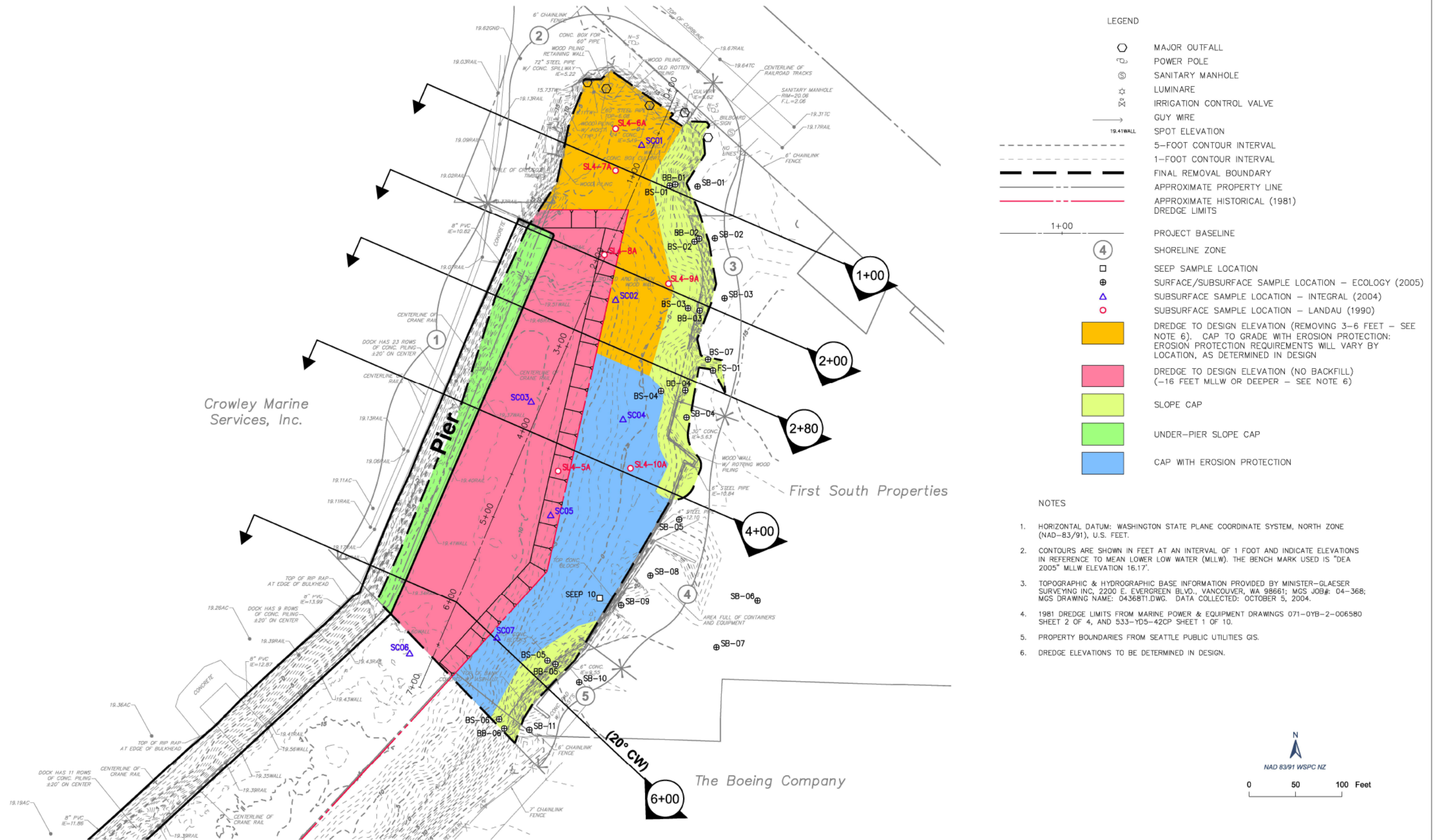


Figure 5-9
Cross Section - Station 6+00
Alternative 2 - Capping, Targeted Sediment Removal, and Habitat Enhancement
Slip 4 EE/CA



Map Document: (FG-Cross Sections.dwg) - Layout: Alt 3 - XSEC 1+00 & 2+00
2/7/2006 - 9:29:09 AM

- NOTES:
1. BULKHEAD, REVETMENT, AND FENDER PILE DETAILS FROM MARINE POWER AND EQUIPMENT CO., INC. DESIGN DRAWING NO. 533-YD5-42CP. UNDER-PIER PILING NOT SHOWN. AS-BUILT CONDITIONS MAY VARY.
 2. DREDGE ELEVATIONS TO BE DETERMINED IN DESIGN.
 3. DREDGE ELEVATIONS IN INNER BERTH TO BE DETERMINED IN DESIGN. CONFIRMATION SAMPLING AND CONTINGENCY ACTIONS TO ENSURE FINAL SURFACE MEETS SQS.

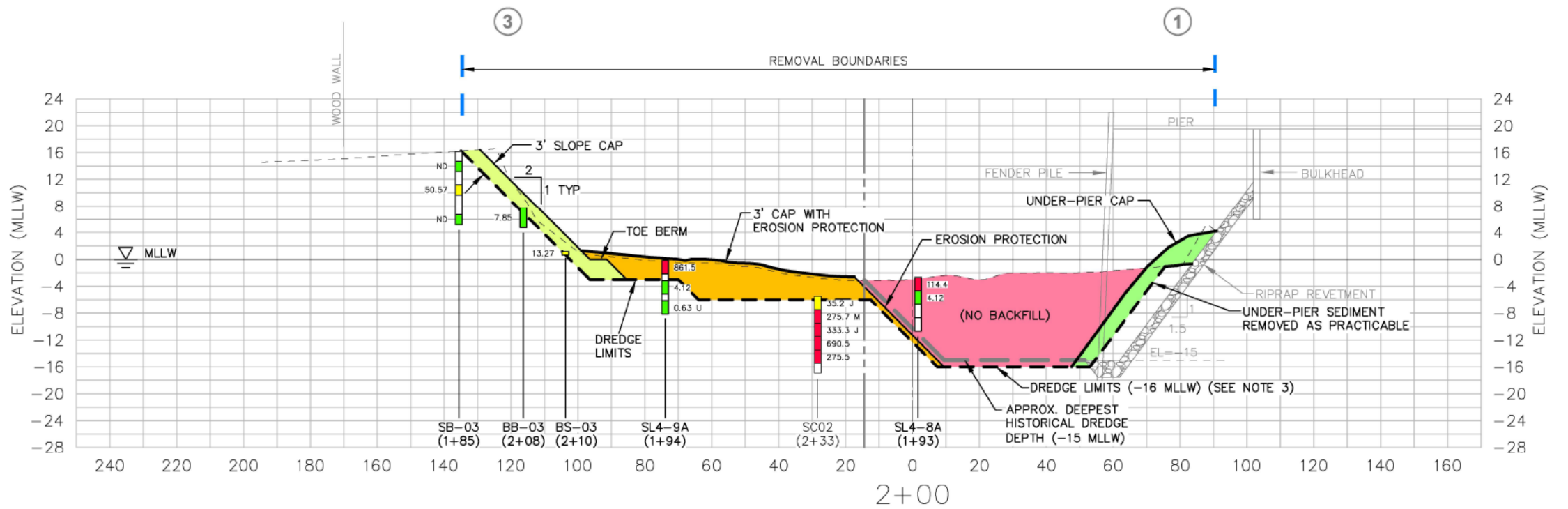
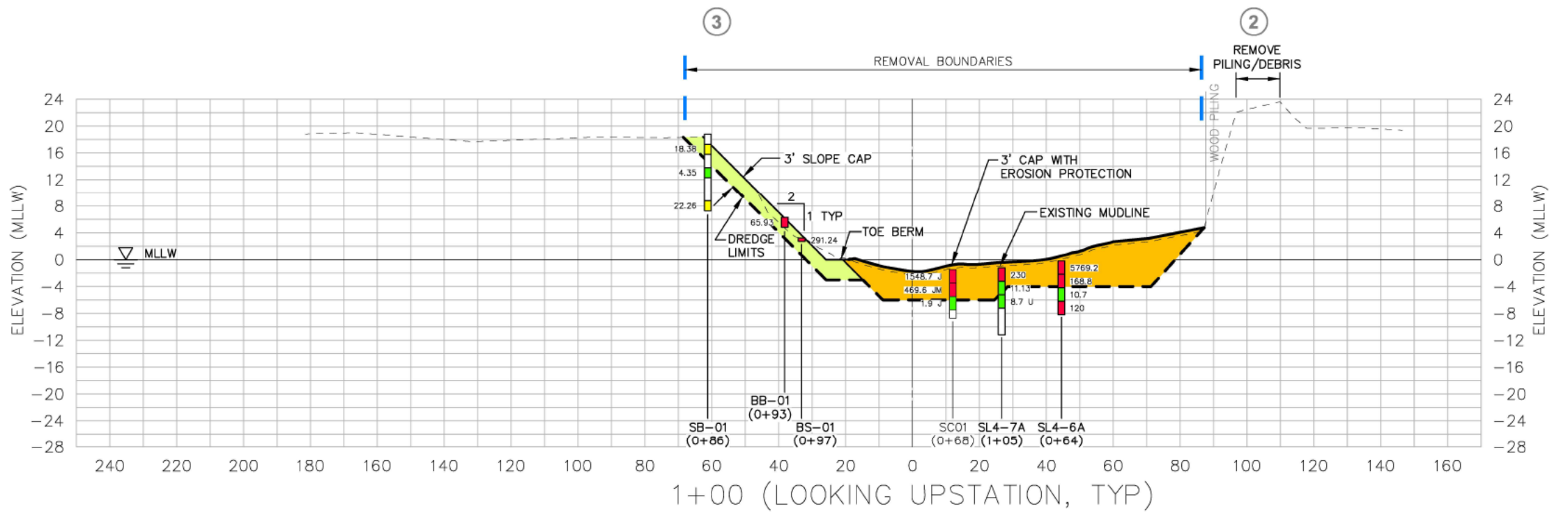
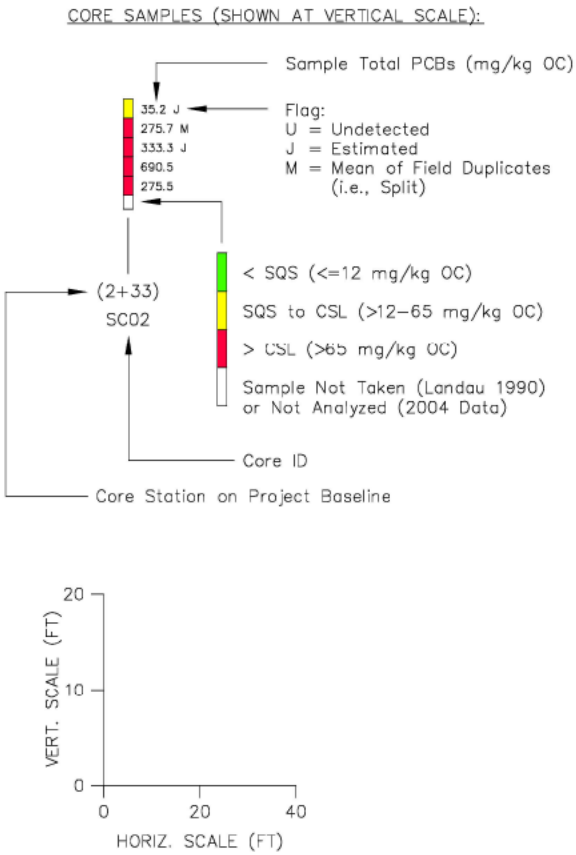
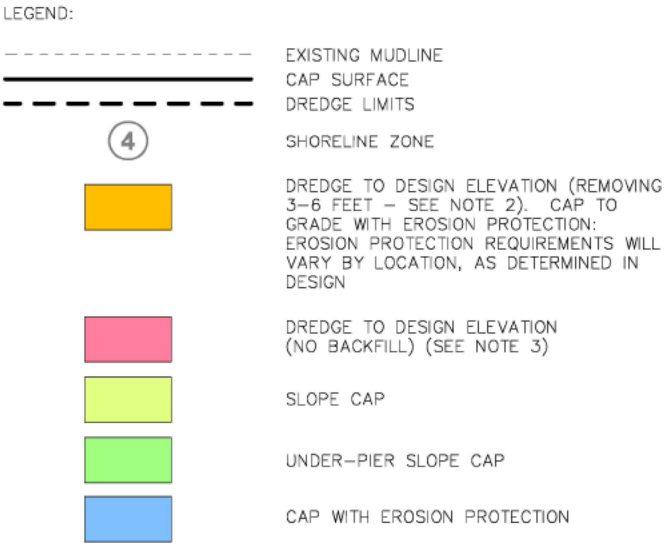
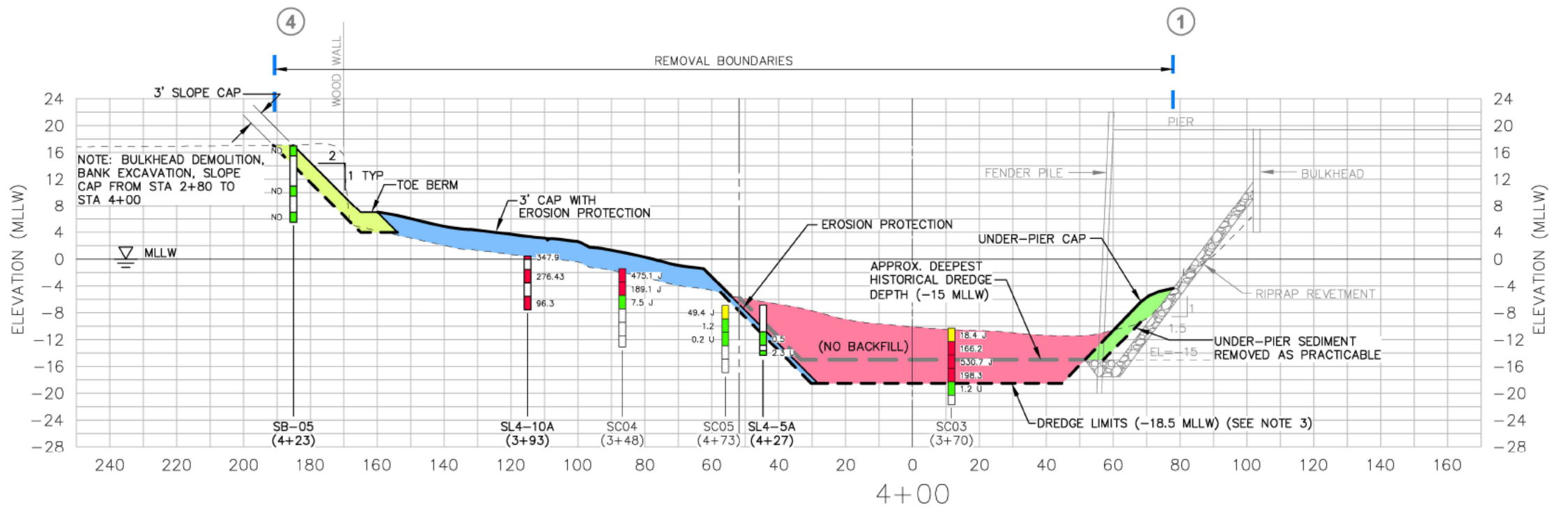
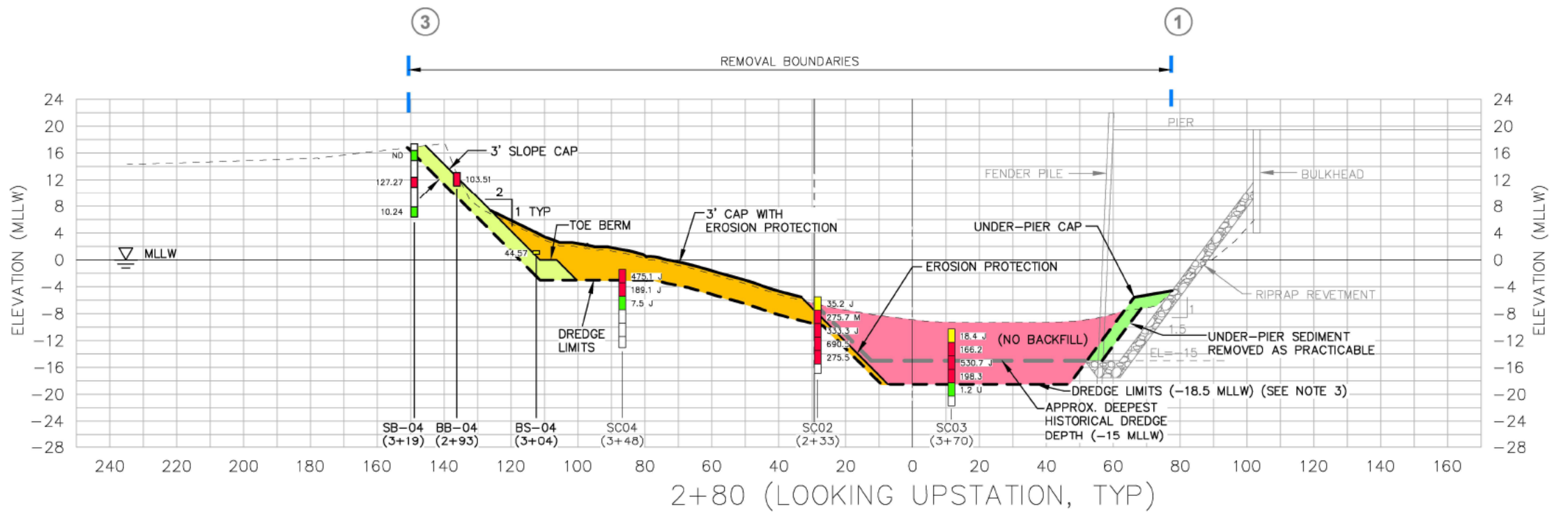
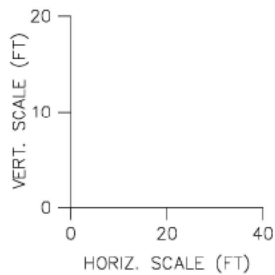
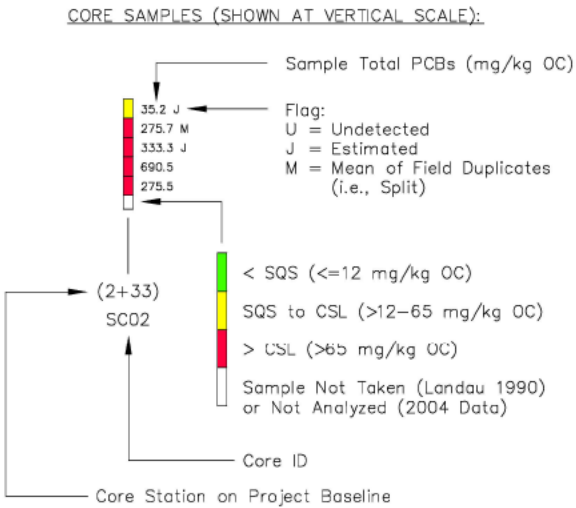
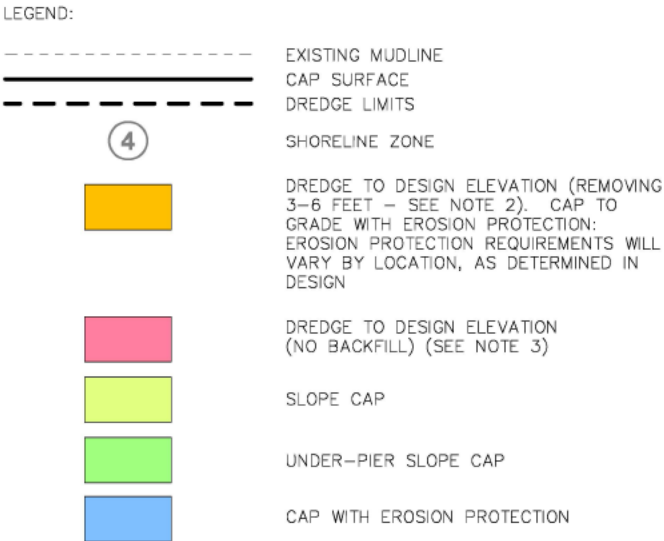


Figure 5-11
Cross Sections - Stations 1+00, 2+00
Alternative 3 - Inner Berth Sediment Removal and Capping
Slip 4 EE/CA

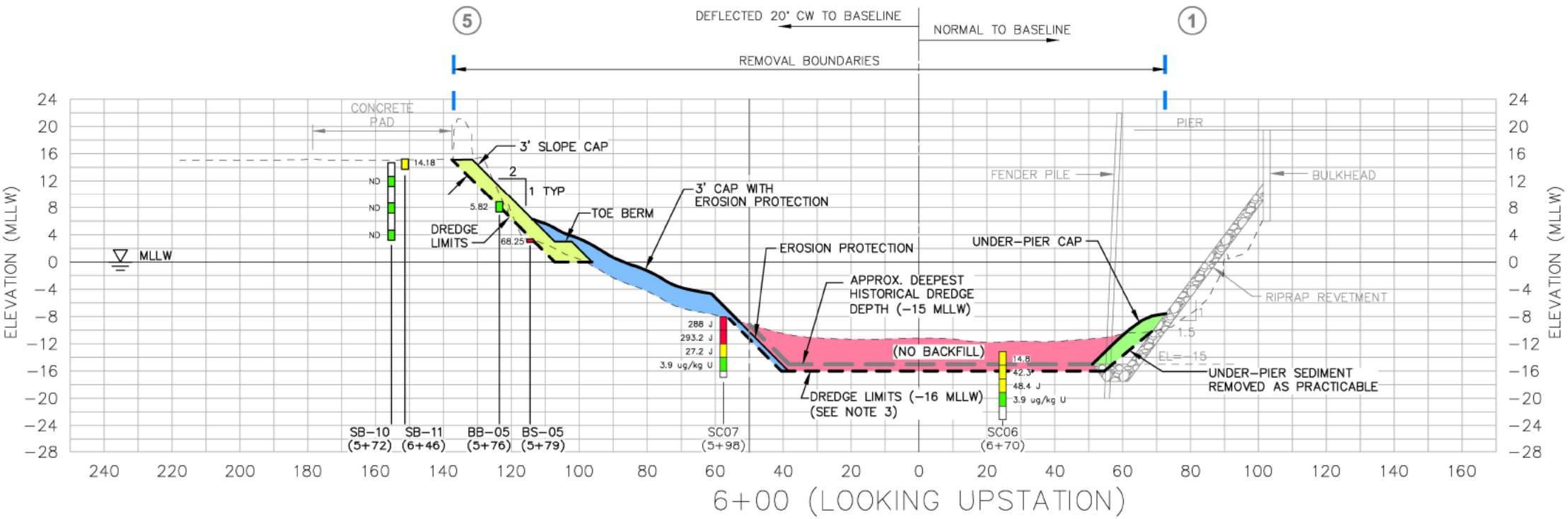
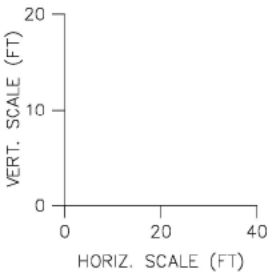
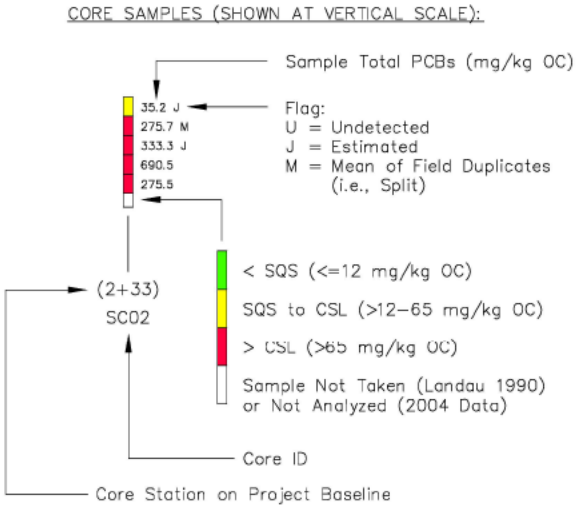
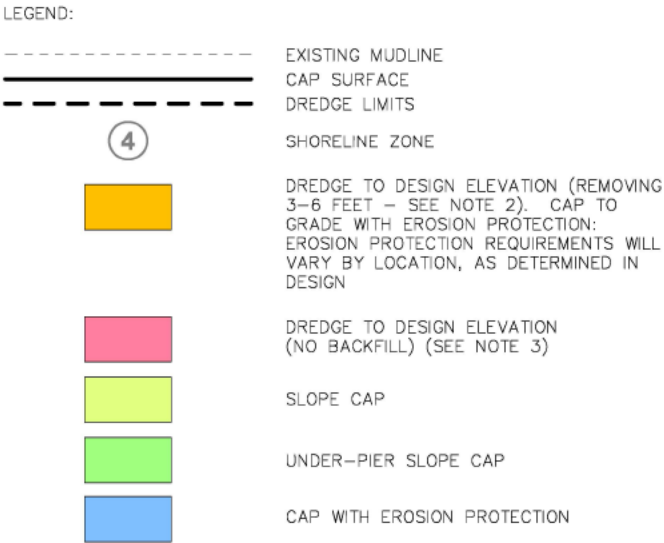
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2/7/2006 - 9:29:38 AM

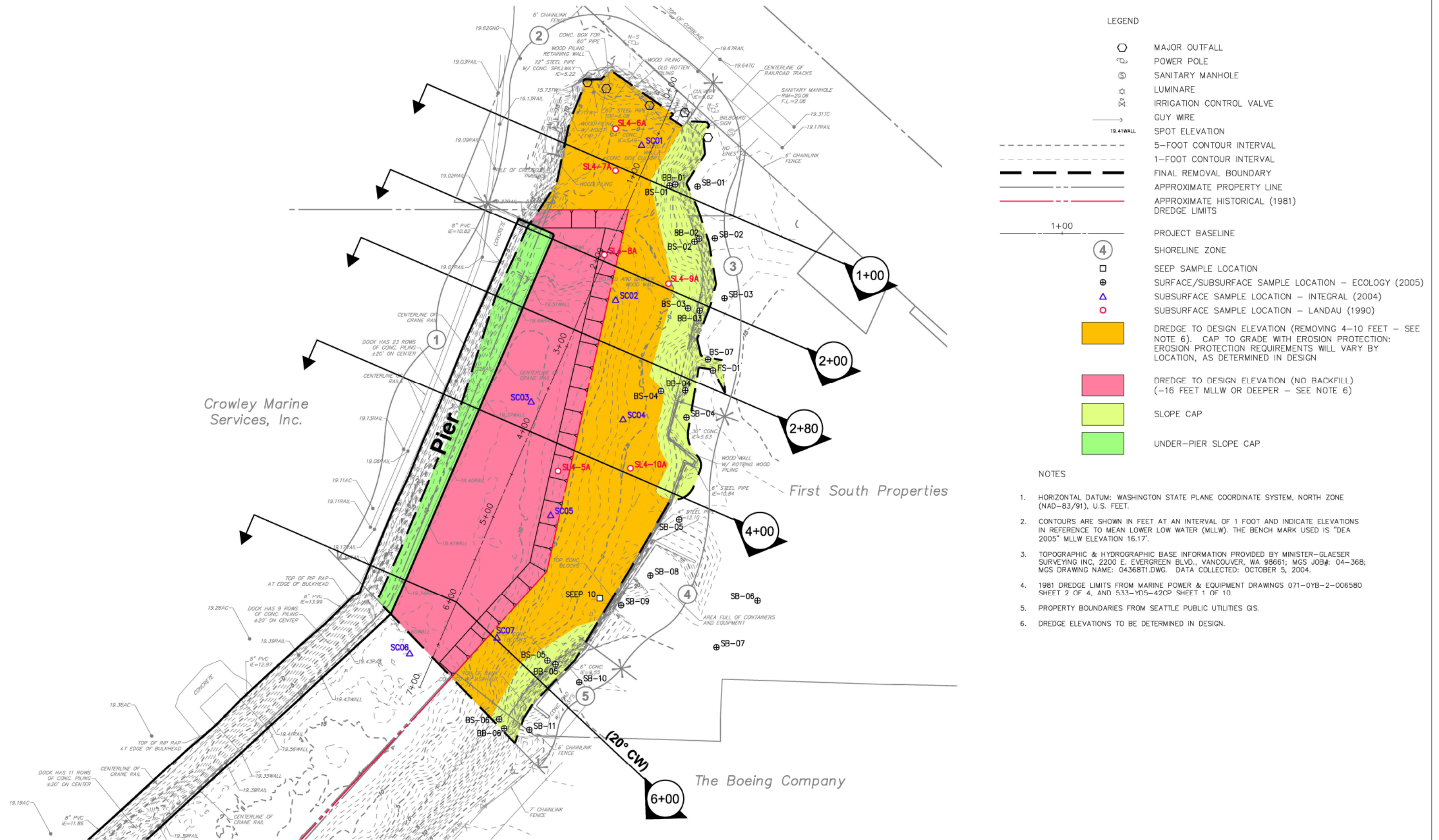
- NOTES:
1. BULKHEAD, REVETMENT, AND FENDER PILE DETAILS FROM MARINE POWER AND EQUIPMENT CO., INC. DESIGN DRAWING NO. 533-YD5-42CP. UNDER-PIER PILING NOT SHOWN. AS-BUILT CONDITIONS MAY VARY.
 2. DREDGE ELEVATIONS TO BE DETERMINED IN DESIGN.
 3. DREDGE ELEVATIONS IN INNER BERTH TO BE DETERMINED IN DESIGN. CONFIRMATION SAMPLING AND CONTINGENCY ACTIONS TO ENSURE FINAL SURFACE MEETS SQS.



Map Document: (FG-Cross Sections.dwg) - Layout: Alt 3 - XSEC 6+00
2/7/2006 - 9:30:09 AM

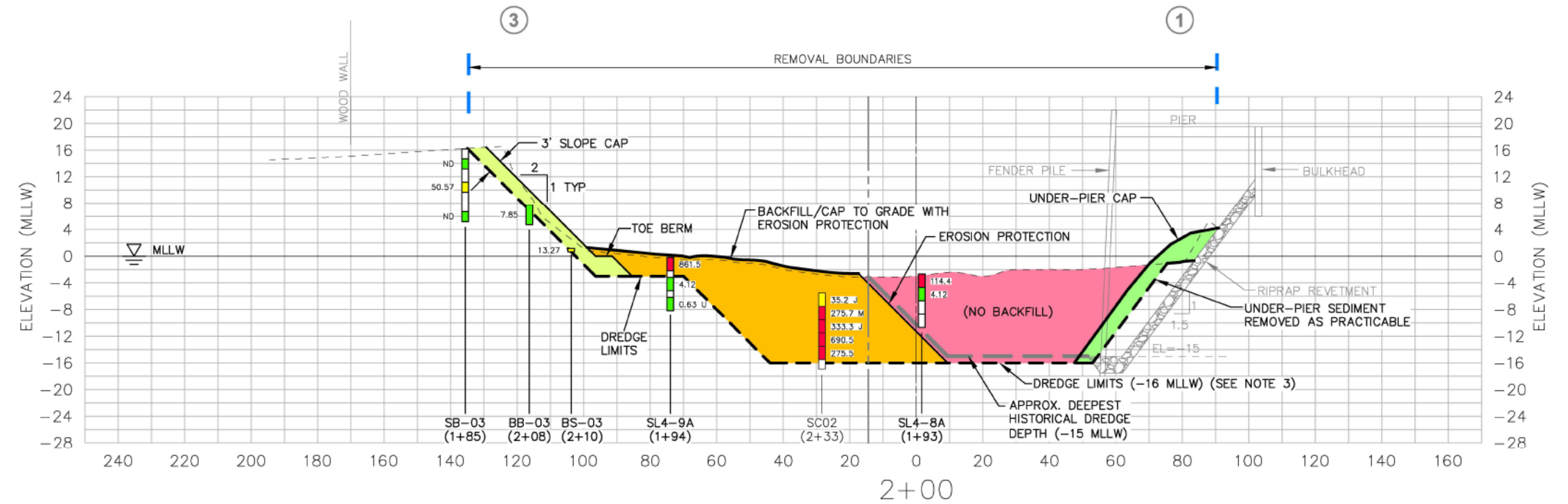
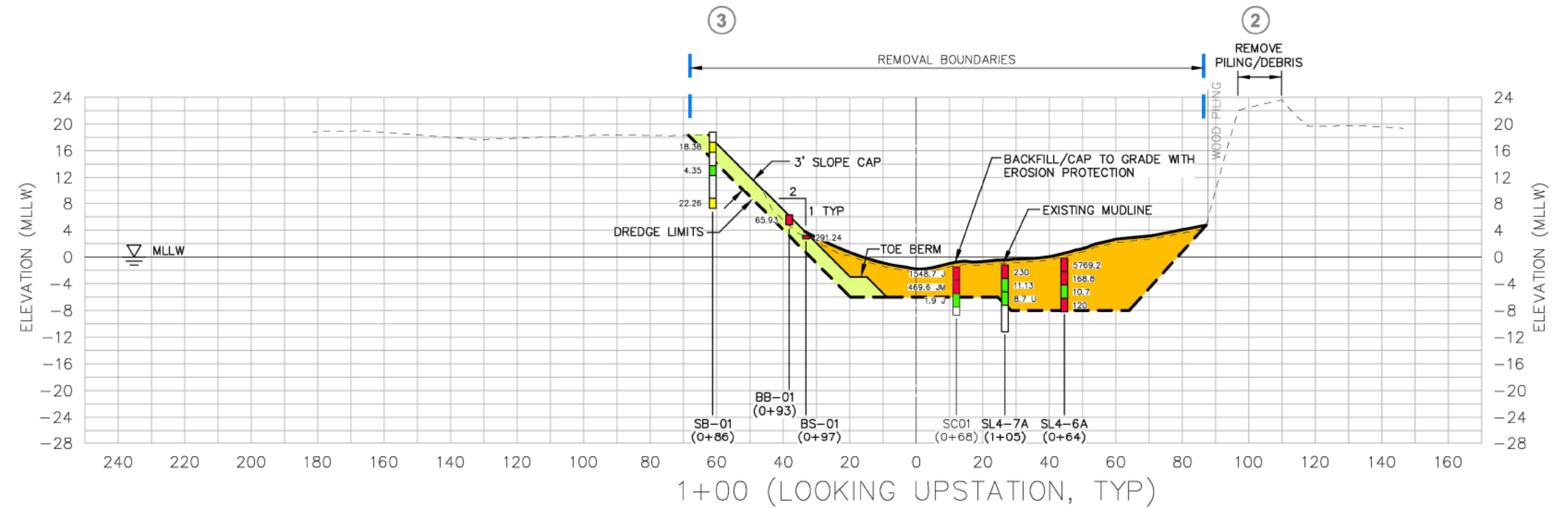
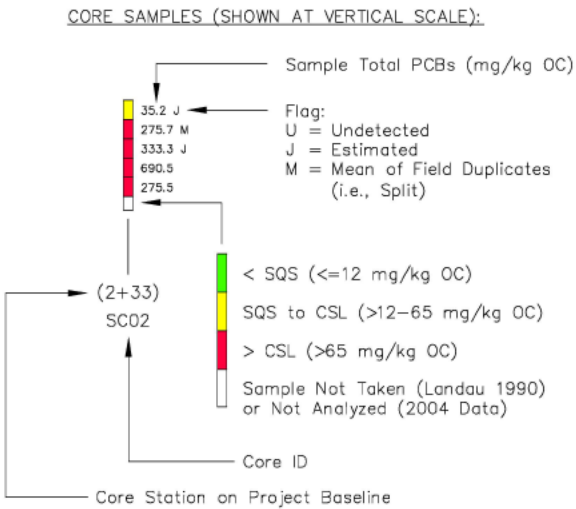
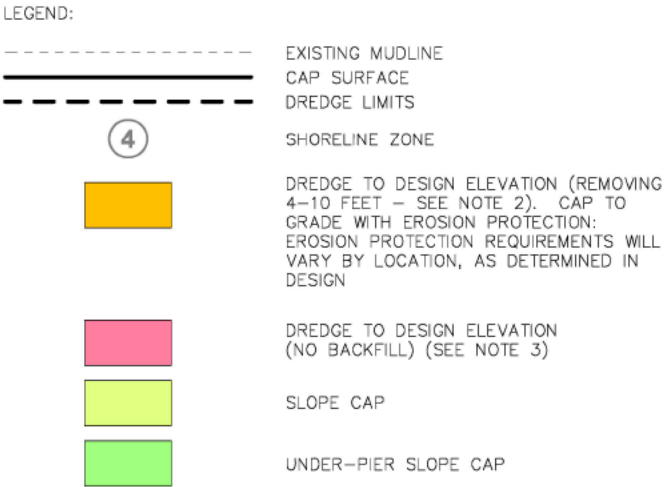
- NOTES:
1. BULKHEAD, REVETMENT, AND FENDER PILE DETAILS FROM MARINE POWER AND EQUIPMENT CO., INC. DESIGN DRAWING NO. 533-YD5-42CP. UNDER-PIER PILING NOT SHOWN. AS-BUILT CONDITIONS MAY VARY.
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Map Document: (FG-Cross Sections.dwg) - Layout: Alt 4 - XSEC 1+00 & 2+00
2/7/2006 - 9:31:03 AM

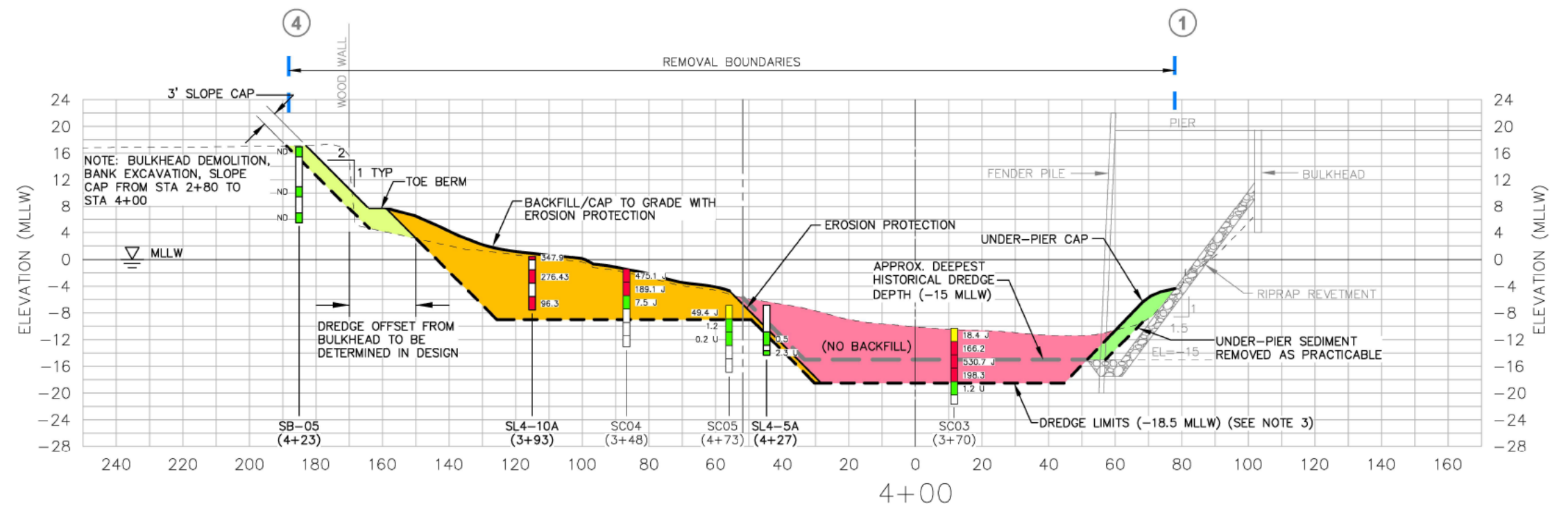
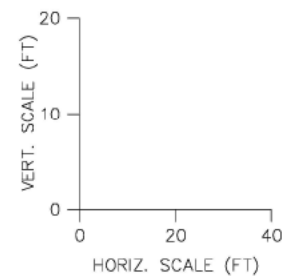
- NOTES:
1. BULKHEAD, REVETMENT, AND FENDER PILE DETAILS FROM MARINE POWER AND EQUIPMENT CO., INC. DESIGN DRAWING NO. 533-YD5-42CP. UNDER-PIER PILING NOT SHOWN. AS-BUILT CONDITIONS MAY VARY.
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 3. DREDGE ELEVATIONS IN INNER BERTH TO BE DETERMINED IN DESIGN. CONFIRMATION SAMPLING AND CONTINGENCY ACTIONS TO ENSURE FINAL SURFACE MEETS SQS.



Map Document: (FG-Cross Sections.dwg) - Layout: Alt 4 - XSEC 2+80 & 4+00
2/7/2006 - 9:31:32 AM

- LEGEND:

CORE SAMPLES (SHOWN AT VERTICAL SCALE):



Map Document: (FG-Cross Sections.dwg) - Layout: Alt 4 - XSEC 6+00
2/7/2006 - 9:31:56 AM

- NOTES:
1. BULKHEAD, REVETMENT, AND FENDER PILE DETAILS FROM MARINE POWER AND EQUIPMENT CO., INC. DESIGN DRAWING NO. 533-YD5-42CP. UNDER-PIER PILING NOT SHOWN. AS-BUILT CONDITIONS MAY VARY.
 2. DREDGE ELEVATIONS TO BE DETERMINED IN DESIGN.
 3. DREDGE ELEVATIONS IN INNER BERTH TO BE DETERMINED IN DESIGN. CONFIRMATION SAMPLING AND CONTINGENCY ACTIONS TO ENSURE FINAL SURFACE MEETS SQS.

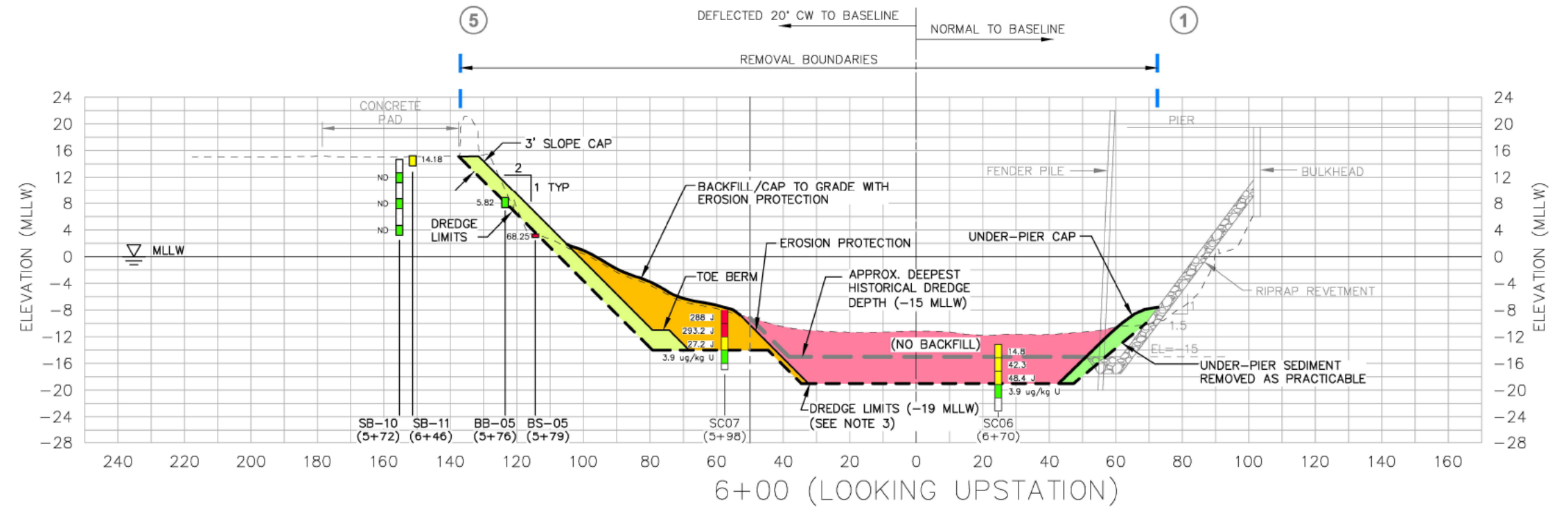
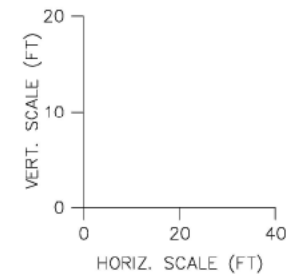
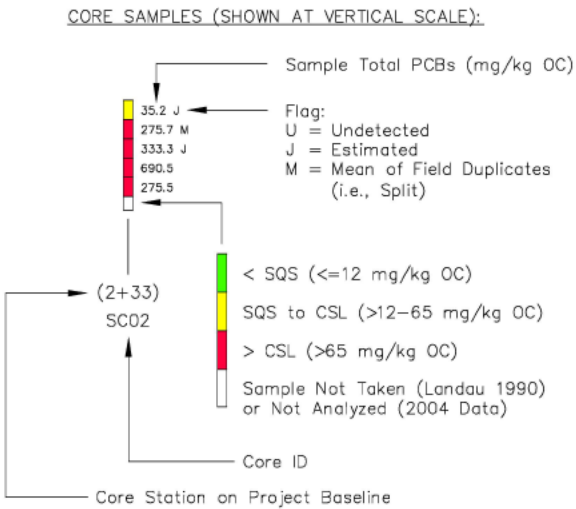
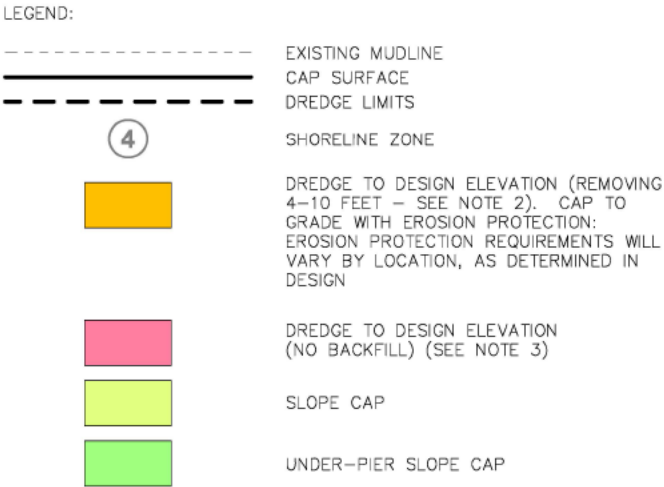


Table 2-1. Slip 4 Outfalls (Tetra Tech 1988a,b; Schmoyer 2003, 2006a,b pers. comm.; Ecology 2005).

Name	Outfall Diameter (inches)	Drainage Area (acres)	Location
I-5 Storm Drain	72	~140	Located at head of Slip 4.
Georgetown Flume	60 ^a	Unknown	Located at head of Slip 4.
North Boeing Field SD ^b	24	3 (SD)	Located at head of Slip 4.
King County Airport SD #3/PS44 EOF	60	290 (SD) 75 (EOF) ^c	Located at head of Slip 4.
East Marginal Way PS EOF ^d	36	318	Located at head of Slip 4.
Private SD	8	Unknown	Located at Crowley Marine property.
Private SD	8	Unknown	Located at Crowley Marine property.
Private SD	8	Unknown	Located at Crowley Marine property.
Private SD	8	Unknown	Located at Crowley Marine property.
Private SD	8	Unknown	Located at Crowley Marine property.
Private SD	8	Unknown	Located at Crowley Marine property.
Private SD	6	Unknown	Located at First South Properties.
Private SD	6	Unknown	Located at First South Properties.
Private SD	4	Unknown	Located at First South Properties.
Private SD	6	Unknown	Located at First South Properties.
Private SD	6	Unknown	Located at First South Properties.
Private SD	24	Unknown	Located at Boeing Plant 2.
Private SD	24	Unknown	Located at Boeing Plant 2.

^a Drawings and survey notes indicate a 60" pipe in a 72" box culvert.

^b The emergency overflow (EOF) from this drain has been rerouted to the King County Airport SD #3/PS44 EOF.

^c SPU records indicate that there have been no overflows from this pump station in the last five years (Schmoyer 2004, pers. comm.).

^d There has not been a recorded overflow to Slip 4 from the East Marginal Way PS since recordkeeping began in the 1970s.

Table 2-2. Endangered, Threatened, or Candidate Species in the LDW (SEA 2004, Windward et al. 2005, WDFW 2004).

	Federal			State		
	Threatened	Candidate	Species of Concern	Threatened	Candidate	Sensitive Species
Chinook salmon	X				X	
Coho salmon		X				
Bull trout	X				X	
Pacific cod					X	
River lamprey			X		X	
Pacific herring					X	
Walleye pollack					X	
Rockfish					X	
Bald eagle	X			X		
Peregrine falcon			X			X
Purple martin					X	
Merlin					X	
Common murre					X	
Common loon					X	
Western grebe					X	

Table 2-3. Washington State Sediment Management Standards Numerical Criteria (WAC 173-204).

	SQS	CSL/MCUL
Metals	(mg/kg, dry weight)	
Antimony	---	---
Arsenic	57	93
Cadmium	5.1	6.7
Chromium	260	270
Copper	390	390
Lead	450	530
Mercury	0.41	0.59
Nickel	---	---
Silver	6.1	6.1
Zinc	410	960
Organics	(mg/kg organic carbon)	
<i>LPAHs</i>	370	780
Naphthalene	99	170
Acenaphthylene	66	66
Acenaphthene	16	57
Fluorene	23	79
Phenanthrene	100	480
Anthracene	220	1,200
2-Methylnaphthalene	38	64
<i>HPAHs</i>	960	5,300
Fluoranthene	160	1,200
Pyrene	1,000	1,400
Benz[a]anthracene	110	270
Chrysene	110	460
Benzo[fluoranthene]	230	450
Benzo[a]pyrene	99	210
Indeno(1,2,3-c,d)pyrene	34	88
Dibenzo[a,h]anthracene	12	33
Benzo[ghi]perylene	31	78
<i>Chlorinated Hydrocarbons</i>		
1,3-Dichlorobenzene	---	---
1,4-Dichlorobenzene	3.1	9
1,2-Dichlorobenzene	2.3	2.3
1,2,4-Trichlorobenzene	0.81	1.8
Hexachlorobenzene	0.38	2.3
<i>Phthalates</i>		
Dimethylphthalate	53	53
Diethylphthalate	61	110
Di-n-butylphthalate	220	1,700
Butylbenzylphthalate	4.9	64
Bis(2-ethylhexyl)phthalate	47	78
Di-n-octylphthalate	58	4,500

Table 2-3. Washington State Sediment Management Standards Numerical Criteria (WAC 173-204).

	SQS	CSL/MCUL
<i>Miscellaneous</i>		
Dibenzofuran	15	58
Hexachlorobutadiene	3.9	6.2
Hexachloroethane	---	---
N-nitrosodiphenylamine	11	11
Total PCBs	12	65
<i>Chlorinated Pesticides</i>		
Total DDT	---	---
Aldrin	---	---
Chlordane	---	---
Dieldrin	---	---
Heptachlor	---	---
Lindane	---	---
<i>Volatile Organic Compounds</i>		
Ethylbenzene	---	---
Tetrachloroethene	---	---
Total xylene	---	---
Trichloroethene	---	---
<i>Ionizable Organic Compounds</i>		
	($\mu\text{g/kg}$, dry weight)	
Phenol	420	1,200
2-Methylphenol	63	63
4-Methylphenol	670	670
2,4-Dimethylphenol	29	29
Pentachlorophenol	360	690
Benzyl Alcohol	57	73
Benzoic Acid	650	650

Table 2-4. Known and Potential Chemicals of Concern in Slip 4 Surface Sediments.^a

SMS Chemicals	1990 - 1998			2004		
	No. of Samples Analyzed	No. of Samples Exceeding SQS	No. of Samples Exceeding CSL	No. of Samples Analyzed ^e	No. of Samples Exceeding SQS	No. of Samples Exceeding CSL
PCBs (total)	39	35 ^f	24	30	10	4
Bis(2-ethylhexyl)phthalate	22	14	10	9	2	1
Dibenzo[a,h]anthracene	22	6	0	9	0	0
Indeno(1,2,3-cd)pyrene	22	6	0	9	1	0
Chrysene	22	5	0	9	0	0
Mercury	23	4	1	30	0	0
Fluoranthene	22	4	0	9	0	0
Butyl benzyl phthalate	22	3	0	9	0	0
Total HPAH	22	3	0	9	0	0
Zinc	23	3	0	5	0	0
Lead	23	2	1	5	0	0
Benz[a]anthracene	22	2	0	9	0	0
Benzo[a]fluoranthene (total)	22	2	0	9	0	0
Di-n-octyl phthalate	22	2	0	9	0	0
Phenanthrene	22	2	0	9	0	0
Cadmium	23	1	1	5	0	0
N-Nitrosodiphenylamine	22	1	1	9	0	0
Benzo[a]pyrene	22	1	0	9	0	0
Benzo[ghi]perylene	22	1	0	9	0	0
Phenol	22	0	0	9	1	0
Non-SMS Chemicals						
DDT (total)	10	1 ^b	1 ^c	0	---	---
Dieldrin	10	1 ^b	---	0	---	---
alpha-Chlordane	10	1 ^b	---	0	---	---

^aKnown and potential chemicals of concern defined as detected chemicals exceeding the SQS in one or more surface sediment samples, or for chemicals without SMS numerical criteria, exceeding the PSDDA SL.

^bExceeds PSDDA SL.

^cExceeds PSDDA ML.

^dNo PSDDA ML for this chemical.

^eIncluding intertidal composite sample; does not include field replicates or bank samples.

^fSurface sediment at one station had less than 0.2% TOC and so was not compared to SMS. PCBs (dry-weight) at this location were greater than the LAET but less than the 2LAET.

Table 2-5. PCB Concentrations in Slip 4 Sediments Sampled in 2004 and 2005.^a

Location	Sample	Depth Interval (cm)		PCBs		SQS	CSL
				ug/kg	mg/kg, OC	Exceedance Factor ^c	Exceedance Factor ^d
Surface Samples							
SG01	SG01	0	10	490 <i>J</i>	4.3 <i>J</i>	0.36 <i>J</i>	0.07 <i>J</i>
SG02	SG02	0	10	1620 <i>J</i>	31.3 <i>J</i>	2.61 <i>J</i>	0.48 <i>J</i>
SG03	SG03	0	10	5100	201	16.73	3.09
SG04	SG04	0	10	4940 <i>J</i>	103 <i>J</i>	8.61 <i>J</i>	1.59 <i>J</i>
SG05	SG05	0	10	444 <i>J</i>	8.7 <i>J</i>	0.72 <i>J</i>	0.13 <i>J</i>
SG06	SG06	0	10	4730 <i>JM</i>	148 <i>JM</i>	12.40 <i>JM</i>	2.29 <i>JM</i>
SG06FR ^b	SG41	0	10	1130 <i>J</i>	33.1 <i>J</i>	2.76 <i>J</i>	0.51 <i>J</i>
SG07	SG07	0	10	470	14.8	1.23	0.23
SG08	SG08	0	10	710 <i>J</i>	23.4 <i>J</i>	1.95 <i>J</i>	0.36 <i>J</i>
SG09	SG09	0	10	482 <i>J</i>	13.4 <i>J</i>	1.11 <i>J</i>	0.21 <i>J</i>
SG10	SG10	0	10	306	9.2	0.77	0.14
SG11	SG11	0	10	242 <i>JM</i>	7.7 <i>JM</i>	0.61 <i>JM</i>	0.11 <i>JM</i>
SG11FR	SG43	0	10	239 <i>J</i>	7.1 <i>J</i>	0.59 <i>J</i>	0.11 <i>J</i>
SG12	SG12	0	10	529 <i>J</i>	16.5 <i>J</i>	1.38 <i>J</i>	0.25 <i>J</i>
SG13	SG13	0	10	368	10.5	0.88	0.16
SG14	SG14	0	10	198 <i>J</i>	7.1 <i>J</i>	0.59 <i>J</i>	0.11 <i>J</i>
SG15	SG15	0	10	299 <i>J</i>	10.5 <i>J</i>	0.87 <i>J</i>	0.16 <i>J</i>
SG16	SG16	0	10	126 <i>J</i>	15.4 <i>J</i>	1.29 <i>J</i>	0.24 <i>J</i>
SG17	SG17	0	10	119	3.9	0.33	0.06
SG18	SG18	0	10	130 <i>J</i>	4.1 <i>J</i>	0.34 <i>J</i>	0.06 <i>J</i>
SG19	SG19	0	10	154	5.4	0.45	0.08
SG20	SG20	0	10	179 <i>J</i>	5.8 <i>J</i>	0.48 <i>J</i>	0.09 <i>J</i>
SG21	SG21	0	10	158 <i>J</i>	5.3 <i>J</i>	0.44 <i>J</i>	0.08 <i>J</i>
SG22	SG22	0	10	145 <i>J</i>	5.2 <i>J</i>	0.43 <i>J</i>	0.08 <i>J</i>
SG23	SG23	0	10	36	6.7	0.56	0.10
SG24	SG24	0	10	99 <i>J</i>	3.4 <i>J</i>	0.29 <i>J</i>	0.05 <i>J</i>
SG25	SG25	0	10	116 <i>J</i>	4.5 <i>J</i>	0.38 <i>J</i>	0.07 <i>J</i>
SG26	SG26	0	10	129 <i>J</i>	2.9 <i>J</i>	0.24 <i>J</i>	0.04 <i>J</i>
SG27	SG27	0	10	77 <i>J</i>	2.5 <i>J</i>	0.20 <i>J</i>	0.04 <i>J</i>
SG28	SG28	0	10	72 <i>J</i>	4.3 <i>J</i>	0.36 <i>J</i>	0.07 <i>J</i>
SG29	SG29	0	10	210 <i>J</i>	7.2 <i>J</i>	0.60 <i>J</i>	0.11 <i>J</i>
IC01	IC01	0	10	1650	154	12.83	2.37
Subsurface Cores							
SC01	SC01A	0	61	35000	1549	129.06	23.83
SC01	SC01B	61	122	1390 <i>M</i>	470 <i>M</i>	39.10 <i>M</i>	7.22 <i>M</i>
SC01	SC01C	122	183	3.9 <i>J</i>	1.9 <i>J</i>	0.16 <i>J</i>	0.03 <i>J</i>
SC02	SC02A	0	61	1200 <i>J</i>	35.2 <i>J</i>	2.93 <i>J</i>	0.54 <i>J</i>
SC02	SC02B	61	122	8300 <i>MJ</i>	276 <i>MJ</i>	22.90 <i>MJ</i>	4.24 <i>MJ</i>
SC02	SC02C	122	183	10900	333	27.78	5.13
SC02	SC02D	183	244	17400 <i>J</i>	690 <i>J</i>	57.54 <i>J</i>	10.62 <i>J</i>
SC02	SC02E	244	305	5400	276	22.96	4.24
SC03	SC03A	0	61	560 <i>J</i>	18.4 <i>J</i>	1.53 <i>J</i>	0.28 <i>J</i>
SC03	SC03B	61	122	4820 <i>J</i>	166 <i>J</i>	13.85 <i>J</i>	2.56 <i>J</i>
SC03	SC03C	122	183	14700	531	44.22	8.16
SC03	SC03D	183	244	2340	198	16.53	3.05
SC03	SC03E	244	305	3.9 <i>U</i>	1.2 <i>U</i>	0.10 <i>U</i>	0.02 <i>U</i>
SC04	SC04A	0	61	14300 <i>J</i>	475 <i>J</i>	39.59 <i>J</i>	7.31 <i>J</i>

Table 2-5. PCB Concentrations in Slip 4 Sediments Sampled in 2004 and 2005.^a

Location	Sample	Depth Interval (cm)		PCBs		SQS	CSL
				ug/kg	mg/kg, OC	Exceedance Factor ^c	Exceedance Factor ^d
SC04	SC04B	61	122	9700	189	15.76	2.91
SC04	SC04C	122	183	300	7.5	0.62	0.12
SC05	SC05A	0	61	1310	49.4	4.12	0.76
SC05	SC05B	61	122	26.6	1.2	0.10	0.02
SC05	SC05C	122	183	3.9 <i>U</i>	0.2 <i>U</i>	0.02 <i>U</i>	0.00 <i>U</i>
SC06	SC06A	0	61	354 <i>J</i>	14.8 <i>J</i>	1.23 <i>J</i>	0.23 <i>J</i>
SC06	SC06B	61	122	990 <i>J</i>	42.3 <i>J</i>	3.53 <i>J</i>	0.65 <i>J</i>
SC06	SC06C	122	183	770 <i>J</i>	48.4 <i>J</i>	4.04 <i>J</i>	0.75 <i>J</i>
SC06	SC06D	183	244	3.9 <i>U</i>	na ^e	0.03 ^e	0.01 ^e
SC07	SC07A	0	61	6900 <i>J</i>	288 <i>J</i>	24.10 <i>J</i>	4.43 <i>J</i>
SC07	SC07B	61	122	7300	293	24.42	4.51
SC07	SC07C	122	183	372	27.2	2.26	0.42
SC07	SC07D	183	244	3.9 <i>U</i>	na ^e	0.03 ^f	0.01 ^f
SC09 ^g	SC-09-0-2	0	61	22.1	1.6	0.13	0.02
SC09 ^g	SC-09-2-4	61	122	3.9 <i>U</i>	0.58 <i>U</i>	0.05 <i>U</i>	0.01 <i>U</i>
SC09 ^g	SC-09-4-6	122	183	3.9 <i>U</i>	0.96 <i>U</i>	0.08 <i>U</i>	0.01 <i>U</i>
SC09 ^g	SC-09-6-8	183	244	3.9 <i>U</i>	1.3 <i>U</i>	0.11 <i>U</i>	0.02 <i>U</i>
SC09 ^g	SC-09-8-10	244	305	3.9 <i>U</i>	0.83 <i>U</i>	0.07 <i>U</i>	0.01 <i>U</i>
SC11 ^g	SC11-0-2	0	61	1770	77	6.42	1.18
SC11 ^g	SC11-2-4	61	122	600	49	4.08	0.75
SC11 ^g	SC11-4-6	122	183	3.9 <i>U</i>	0.90 <i>U</i>	0.08 <i>U</i>	0.01 <i>U</i>
SC11 ^g	SC11-6-8	183	244	3.9 <i>U</i>	0.72 <i>U</i>	0.06 <i>U</i>	0.01 <i>U</i>
SC11 ^g	SC11-8-10	244	305	3.9 <i>U</i>	0.77 <i>U</i>	0.06 <i>U</i>	0.01 <i>U</i>
SC11 ^g	SC11-10-12	305	366	3.8 <i>U</i>	0.70 <i>U</i>	0.06 <i>U</i>	0.01 <i>U</i>
Bank Samples 2004 (Integral 2004a)							
BK01	BK01	0	10	23	2.4	0.20	0.04
BK02	BK02	0	10	4700 <i>M</i>	47 <i>M</i>	3.91 <i>M</i>	0.72 <i>M</i>
BK02FR	BK08	0	10	2710	28.9	2.40	0.44
BK03	BK03	0	10	850	48.6	4.05	0.75
BK04	BK04	0	10	790	20.2	1.68	0.31
BK05	BK05	0	10	1300	26.3	2.19	0.40
BK06	BK06	0	10	7800	402	33.51	6.19
Bank Samples 2005 (Paramatrix 2005; Bach 2005a)							
BK-06A	BK-06A	0	10	360	16.7	1.39	0.26
BK-06B	BK-06B	0	10	140	5.4	0.45	0.08
BK-06C	BK-06C	0	10	440	11.3	0.94	0.17
BS-01	BS-01	--	15	9640	291.24	24.27	4.48
BS-02	BS-02	--	15	617	60.49	5.04	0.93
BS-03	BS-03	--	15	215	13.27	1.11	0.20
BS-04	BS-04	--	15	365	44.57	3.71	0.69
BS-05	BS-05	--	15	1440	68.25	5.69	1.05
BS-06	BS-06	--	15	876	53.41	4.45	0.82
BB-01	BB-01	--	46	1800	65.93	5.49	1.01
BB-02	BB-02	--	46	9540	829.57	69.13	12.76
BB-03	BB-03	--	91	146	7.85	0.65	0.12
BB-04	BB-04	--	61	1594	103.51	8.63	1.59

Table 2-5. PCB Concentrations in Slip 4 Sediments Sampled in 2004 and 2005.^a

Location	Sample	Depth Interval (cm)		PCBs		SQS	CSL
				ug/kg	mg/kg, OC	Exceedance Factor ^c	Exceedance Factor ^d
BB-05	BB-05	--	46	210	5.82	0.49	0.09
BB-06	BB-06	--	46	711	67.71	5.64	1.04

Notes:

U = Undetected.

J = Estimated. The result was qualified as estimated but met criteria for acceptance of data for use in site evaluation.

M = Mean of duplicate (i.e., field split) results.

^aBoxes indicate concentrations exceeding SQS; shading indicates concentrations exceeding CSL.

^bFR indicates field replicate sample. Field replicates are additional field samples collected at a station after obtaining the

^cSQS Exceedance Factor = sample concentration/SQS (PCBs SQS = 12 mg/kg OC).

^dCSL Exceedance Factor = sample concentration/CSL (PCBs CSL = 65 mg/kg OC).

^eTOC is less than 0.2% so concentration is not TOC-normalized.

^fDry weight concentration compared to lowest apparent effects threshold (LAET) due to low TOC.

^gSample analyzed by The Boeing Company (Landau 1990).

Table 2-6. Concentrations of Detected Chemicals other than PCBs that Exceed SMS in Slip 4 Sediments.

Chemical	Station	Sample Depth (cm)	Concentration	SQS EF ^a	CSL EF ^b
Organics					
Bis(2-ethylhexyl) phthalate	SG06	0 - 10	102 mg/kg, OC	2.174	1.310
Bis(2-ethylhexyl) phthalate	SG06FR (SG41) ^c	0 - 10	132 mg/kg, OC	2.808	1.692
Bis(2-ethylhexyl) phthalate	SG16	0 - 10	51 mg/kg, OC	1.094	0.659
Indeno(1,2,3-cd)pyrene	SG06FR (SG41)	0 - 10	35 mg/kg, OC	1.035	0.400
Phenol	SG16	0 - 10	480 ug/kg	1.143	0.400
Metals					
Mercury	SC01	0 - 61	10.3 mg/kg	25.122	17.458
Mercury - reanalysis	SC01	0 - 61	0.99 mg/kg	2.415	1.678
Mercury	SC02	122 - 183	0.51 mg/kg	1.244	0.864
Mercury	SC02	183 - 244	0.82 mg/kg	2.000	1.390
Mercury	SC04	122 - 183	0.71 mg/kg	1.732	1.203
Mercury	SC04	183 - 244	0.49 mg/kg	1.195	0.831
Mercury	SC07	61 - 122	0.47 mg/kg	1.146	0.797
Silver	SC02	183 - 244	6.4 mg/kg	1.049	1.049

^a SQS Exceedance Factor = sample concentration/SQS.

^b CSL Exceedance Factor = sample concentration/CSL.

^c FR indicates field replicate sample. Field replicates are additional field samples collected at a station after obtaining the primary or normal sample and repositioning the sampling vessel.

Table 2-7. Summary of Groundwater Investigations.

Facility	Investigation	Date	No. of Wells Sampled	Chemicals Analyzed					
				VOC	SVOC	PCBs	TPH	Metals	Other
First South Properties									
	Environmental Site Assessment, First Interstate Bank of Washington Property (Landau 1990)	June 1990	3	X	X	X	X	X	
	Underground Tank Removal and Groundwater/Soil Quality Report, Parcel E, Evergreen Marine Leasing Property (Hart Crowser 1991)	October 1990, January 1991, April 1991	4	X	X		X		
	Additional Independent Remedial Action Report, Former Evergreen Marine Leasing Property (Hart Crowser 1996)	1996 - ? (monitoring)	3				X		
Crowley	Assessment of Marine Power and Equipment Sites (Weston 1988, in Hart Crowser 1989a)	1988	2	X	X	X		X	pesticides
	Environmental Assessment - Parcel F Soil and Groundwater Conditions, Evergreen Marine Leasing Property (Hart Crowser 1989a)	November 1988 (phase 1)	2	X	X	X		X	pesticides
	Environmental Site Assessment, First Interstate Bank of Washington Property (Landau 1990)	June 1990	6	X	X	X	X	X	
	Environmental Assessment - Parcel D Soil and Groundwater Conditions, Evergreen Marine Leasing Property (Hart Crowser 1989b)	November 1988 (phase 1)	2	X	X	X		X	pesticides
		June 1989 (phase 2)	2					arsenic	
	Supplemental Site Characterization Report, Parcel D. Evergreen Marine Leasing Property (Hart Crowser 1990)	September 1990	7		PAHs			arsenic	

Table 2-7. Summary of Groundwater Investigations.

Facility	Investigation	Date	No. of Wells Sampled	Chemicals Analyzed					
				VOC	SVOC	PCBs	TPH	Metals	Other
	<i>Site Investigation Crowley Marine Services 8th Avenue South Facility (SEACOR 1994)</i>	July 1994	3	X			X	lead	
The Boeing Company	<i>Phase II Subsurface Environmental Assessment, Proposed Integrated Aircraft Systems Laboratory Building (Weston 1990)</i>	1990	6	X				X	oil & grease
	<i>Release Assessment, Boeing-Plant 2 (Weston 1994)</i>	1994	3			unknown		X	

Table 2-8. LDW Phase 1 Ecological Risk Assessment Summary (Windward 2003b).

Group	Representative Species (receptor of concern)	COPCs	Risk Characterization
Benthic Invertebrates	Crab	PCBs, TBT, metals, other organic compounds	Low, except for arsenic ^a
Fish	English sole Bull trout ^b Wild juvenile chinook salmon ^b	PCBs, PAHs, TBT, DDT, arsenic, copper, mercury	Arsenic, copper, and PCB exposure concentration greater than concentrations associated with adverse effects for one or more of the representative fish species. PAHs, mercury, and tributyltin exposure estimates between the no-effects level and the adverse-effects level.
Birds and Mammals	Great blue heron Spotted sandpiper Bald eagle River otter Harbor seal	PCBs, BEHP, arsenic, copper, lead, mercury, and zinc	PCB exposure of great blue heron may be occurring at levels associated with adverse effects (eggs). PCB, mercury, lead, arsenic exposure estimates greater than no-effects levels for one or more wildlife species; no dietary exposures greater than doses associated with adverse effects to survival, growth, or reproduction.
Plants	Emergent aquatic plants	Lead, mercury, PCBs, and zinc	Exposure concentrations less than soil PCB concentrations associates with no effect, but within low end of the concentration range associates with effects for lead and zinc.

^a Natural background levels of arsenic will be addressed in the Phase 2 ERA.

^b Federally listed threatened or endangered species.

Table 2-9. Comparison of Maximum Chemical Concentrations in Slip 4 Surface Sediments to Human Health Risk-based Concentrations.

		NETFISHING EXPOSURE SCENARIO			BEACH PLAY EXPOSURE SCENARIO		
		Maximum Reported Concentration ^a	Risk-Based Concentration ^b	Potential Human Health Concern?	Maximum Reported Concentration ^c	Risk-Based Concentration ^b	Potential Human Health Concern?
1,2,4-Trichlorobenzene	µg/kg dw	120 <i>U</i>	3,000,000	no	120 <i>U</i>	65,000	no
1,2-Dichlorobenzene	µg/kg dw	120 <i>U</i>	370,000	no	120 <i>U</i>	370,000	no
1,3-Dichlorobenzene	µg/kg dw	120 <i>U</i>	5,200	no	120 <i>U</i>	1,300	no
1,4-Dichlorobenzene	µg/kg dw	120 <i>U</i>	8,100	no	120 <i>U</i>	3,400	no
2,4-Dimethylphenol	µg/kg dw	120 <i>U</i>	1,800,000	no	120 <i>U</i>	120,000	no
2-Methylnaphthalene	µg/kg dw	120 <i>U</i>	na	no	120 <i>U</i>	na	no
2-Methylphenol	µg/kg dw	120 <i>U</i>	4,400,000	no	120 <i>U</i>	310,000	no
4-Methylphenol	µg/kg dw	220	440,000	no	120 <i>U</i>	31,000	no
Acenaphthene	µg/kg dw	120 <i>U</i>	3,800,000	no	120 <i>U</i>	370,000	no
Acenaphthylene	µg/kg dw	120 <i>U</i>	na	no	120 <i>U</i>	na	no
Anthracene	µg/kg dw	280	100,000,000	no	120 <i>U</i>	2,200,000	no
Antimony	mg/kg dw	10 <i>U</i>	82	no	6 <i>U</i>	3.1	undetected ^e
Arsenic	µg/kg dw	20	2.7	yes ^d	6 <i>U</i>	0.39	undetected
Benz[a]anthracene	µg/kg dw	1600	2,900	no	120	620	no
Benzo[a]pyrene	µg/kg dw	2500	290	no	150	620	no
Benzo[b+k]fluoranthene	µg/kg dw	7000 <i>J</i>	na ^f	no	340 <i>J</i>	na ^g	no
Benzo[ghi]perylene	µg/kg dw	930	na	no	120 <i>U</i>	na	no
Benzoic acid	µg/kg dw	1200 <i>U</i>	100,000,000	no	1200 <i>U</i>	100,000,000	no
Benzyl alcohol	µg/kg dw	120 <i>U</i>	100,000,000	no	120 <i>U</i>	1,800,000	no
Bis(2-ethylhexyl) phthalate	µg/kg dw	4500	180,000	no	160	35,000	no
Butylbenzyl phthalate	µg/kg dw	120	100,000,000	no	120 <i>U</i>	1,200,000	no
Cadmium	mg/kg dw	1.8	81	no	6 <i>U</i>	3.7	undetected
Chromium	mg/kg dw	53	448	no	24.4	210	no
Chrysene	µg/kg dw	2400	290,000	no	210	62,000	no
Copper	mg/kg dw	94.8	7,600	no	32.2	290	no
Dibenz[a,h]anthracene	µg/kg dw	280	290	no	120 <i>U</i>	62	undetected
Dibenzofuran	µg/kg dw	120 <i>U</i>	510,000	no	120 <i>U</i>	29,000	no
Dibutyl phthalate	µg/kg dw	120 <i>U</i>	8,800,000	no	120 <i>U</i>	610,000	no
Diethyl phthalate	µg/kg dw	120 <i>U</i>	100,000,000	no	120 <i>U</i>	4,900,000	no
Dimethyl phthalate	µg/kg dw	120 <i>U</i>	100,000,000	no	120 <i>U</i>	100,000,000	no
Di-n-octyl phthalate	µg/kg dw	220	10,000,000	no	120 <i>U</i>	120,000	no
Fluoranthene	µg/kg dw	3900	3,000,000	no	290	230,000	no
Fluorene	µg/kg dw	120 <i>U</i>	3,300,000	no	120 <i>U</i>	260,000	no

Table 2-9. Comparison of Maximum Chemical Concentrations in Slip 4 Surface Sediments to Human Health Risk-based Concentrations.

		NETFISHING EXPOSURE SCENARIO			BEACH PLAY EXPOSURE SCENARIO		
		Maximum Reported Concentration ^a	Risk-Based Concentration ^b	Potential Human Health Concern?	Maximum Reported Concentration ^c	Risk-Based Concentration ^b	Potential Human Health Concern?
Hexachlorobenzene	µg/kg dw	120 <i>U</i>	1,500	no	120 <i>U</i>	300	no
Hexachlorobutadiene	µg/kg dw	120 <i>U</i>	32,000	no	120 <i>U</i>	6,200	no
Hexachloroethane	µg/kg dw	120 <i>U</i>	180,000	no	120 <i>U</i>	35,000	no
Indeno(1,2,3-cd)pyrene	µg/kg dw	1200	2,900	no	120 <i>U</i>	620	no
Lead	mg/kg dw	109	100	yes ^h	17	40	no
Mercury	mg/kg dw	0.4	8.8	no	0.06	0.61	no
Naphthalene	µg/kg dw	130	19,000	no	120 <i>U</i>	5,600	no
Nickel	mg/kg dw	29	4,100	no	27	160	no
N-Nitrosodiphenylamine	µg/kg dw	120 <i>U</i>	500,000	no	120 <i>U</i>	99,000	no
Pentachlorophenol	µg/kg dw	590 <i>U</i>	11,000	no	580 <i>U</i>	3,000	no
Phenanthrene	µg/kg dw	1200	na	no	120 <i>U</i>	na	no
Phenol	µg/kg dw	480	100,000,000	no	120 <i>U</i>	3,700,000	no
Polychlorinated biphenyls	µg/kg dw	5100	1,000	yes	1650 <i>J</i>	220	yes
Pyrene	µg/kg dw	4400	5,400,000	no	420	230,000	no
Silver	mg/kg dw	1	1,000	no	0.4 <i>U</i>	39	no
Zinc	mg/kg dw	256	100,000	no	67.4	2,300	no

Notes:

U = Undetected

J = Estimated

^aIntertidal and subtidal surface sediment concentrations in 2004.

^bDerived by Windward (2003c).

^cIntertidal surface sediment composite sample in 2004.

^dArsenic concentration above Puget Sound background levels (5.03/10.4 mg/kg) at one location (SG-17).

^eChemical is undetected but reporting limit is greater than risk-based concentration.

^fRisk-based concentration (netfishing exposure) for benzo(k)fluoranthene = 29,000 µg/kg.

^gRisk-based concentration (beach play exposure) for benzo(k)fluoranthene = 6,200 µg/kg.

^hExceeds risk-based concentration at one (SG-06) of six stations analyzed for lead in Slip 4; this station also exceeds risk-based concentration for PCBs.

Table 2-10. Chemicals Exceeding SMS¹ in Slip 4 Storm Drains.

Drain	Chemicals Exceeding SMS	Sample Type
King County Airport SD#3/PS44 EOF	Mercury, zinc, BEHP, PCBs Mercury, zinc, acenaphthene, fluorene, benzo(b+k)fluoranthenes, phenanthrene, benzo(g,h,i)perylene, fluoranthene, indeno(1,2,3-cd)pyrene, BEHP, PCBs Copper, lead, zinc, fluorene, phenanthrene, benzo(a)anthracene, benzo(a)pyrene, benzo(b+k)fluoranthenes, benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, BEHP	Sediment trap Inline sediment samples Catch basin sediment
I-5 SD	Zinc, BEHP, PCBs	Sediment trap
Georgetown flume	Lead, mercury, zinc, phenanthrene, fluoranthene, BEHP, acenaphthene, fluorene, benzo(b+k)fluoranthenes, PCBs Zinc, phenanthrene, benzo(b+k)fluoranthenes, benzo(g,h,i)perylene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, PCBs	Inline sediment samples Catch basin sediment
Private outfalls to Slip 4	Zinc, BEHP, butylbenzylphthalate, di-n-octylphthalate	Catch basin sediment

¹ Exceedances of SMS criteria are noted here for comparison purposes only, as the SMS do not apply to storm drain sediments.

Table 4-1. Advantages and Disadvantages of Using Treatment Technologies for Slip 4 Cleanup.

EE/CA Evaluation Criterion	Treatment Advantages	Treatment Disadvantages
Effectiveness	<p>May destroy some or most of the organic contaminants such as PCBs.</p> <p>May reduce amount of PCBs being landfilled.</p> <p>May allow for beneficial use of the treated material.</p> <p>Incineration and high-temperature thermal desorption have proven effectiveness for PCBs.</p>	<p>Effectiveness of advanced soil washing is unproven for these site conditions.</p> <p>Each of the technologies produces waste streams (e.g., off gasses, wastewater) that may contain contaminants and may increase short-term risks.</p> <p>Waste streams from advanced soil washing require landfilling or discharge to water.</p> <p>Treated material may still have residual contamination. Beneficial use may create higher exposures and risks compared to landfilling without treatment. Beneficial use requires careful evaluation.</p>
Implementability	<p>Offsite incineration at established facilities is readily implementable.</p>	<p>Advanced soil washing would require treatability testing, delaying cleanup.</p> <p>Administratively difficult to assess and implement re-use options in a short time frame.</p> <p>Onsite treatment facility requires significant land and infrastructure.</p> <p>Administratively difficult to site a new PCB treatment facility.</p>
Cost	<p>No cost advantages.</p>	<p>Substantially higher costs than direct landfill disposal of untreated materials.</p> <p>Advanced soil washing costs are difficult to predict, and there is substantial potential for cost overruns.</p> <p>Costs may further increase if beneficial use cannot be implemented.</p> <p>Costs of each treatment technology is substantial and disproportionate to any benefits gained.</p> <p>Landfill disposal is a proven, lower-cost alternative.</p>

Table 5-1. Summary of Estimated Quantities Associated with Slip 4 Removal Alternatives.

Action	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Removal Volumes (cy)^a				
Bank Excavation ^{b,c}	7,300	9,700	3,200	4,300
Dredging ^d	700 ^e	4,300	24,000	36,000
Total Volume Removed	8,100	14,000	27,000	40,000
Fill Volumes (cy)^f				
Capping	27,000	27,000	17,000	26,000
Enhanced Natural Recovery ^g	0	0	2,500	3,000
Total Fill Volume	27,000	27,000	20,000	29,000
Cap Areas (acres)				
Capping	3.6	3.6	2.5 ^h	0.73 ⁱ

Notes:

^a All quantities are rounded to two significant figures; minor differences in the totals are due to rounding. All removal volume estimates include a 1-foot pay overdepth.

^b Bank excavation quantities represent the volume of material expected to be removed by land-based equipment working from the upland. Actual equipment and methodology will be determined in the design and in the selected contractor's work plans. Bank excavation includes bank material from the top of bank down to elevations as low as -3 feet MLLW.

^c Bank excavation includes material that could be defined as either "excavation material" or "dredged material." Using the criteria defined by the DMMP (2003), 100% of this material from Slip 4 may be considered to be "dredged material," as removal of this material has demonstrable ecological benefits at the project site. EPA tracks media as "soil" or "sediment." Approximately 70% of the bank excavation material is considered to be "sediment" and 30% is considered "soil."

^d Dredge quantities represent the volume of sediment expected to be removed by floating equipment. Actual equipment and methodology will be determined in the design and in the selected contractor's work plans. Volumes for Alternatives 3 and 4 include allowance for contingency overdredging to address residuals.

^e Sediment removal near the head of Slip 4 under Alternative 1 would likely be accomplished in-the-dry with land-based equipment, but may potentially be dredged with floating equipment.

^f All fill volume estimates include a 1-foot overplacement pay allowance.

^g Enhanced natural recovery represents placement of a thin layer of cap material, and is included as a contingency action for Alternatives 3 and 4.

^h Cap area could range up to 3.6 acres if inner berth area requires capping.

ⁱ Cap area could range up to 3.6 acres if inner berth area requires capping and if backfilled areas are considered a "cap."

Table 5-2. Estimated Costs for Alternative 1.

Item	Estimated Cost
Land Acquisition and Institutional Control Implementation ^a	\$ 700,000
Mob/Demob/Site Prep	\$ 263,000
Bank Excavation and Disposal	\$ 558,000
Dredging and Disposal	\$ 98,000
Capping	\$ 1,235,000
Outfall Modifications	\$ 130,000
Debris Removal and Disposal	\$ 122,000
Construction Engineering, Management, and QA/QC ^b	\$ 710,000
Washington State Sales Tax	\$ 287,000
Design and Project Management ^c	\$ 681,000
Contingency ^d	\$ 770,000
Long-Term Operation & Maintenance (30-yr Present Worth) ^e	\$ 480,000
Total	\$ 6,000,000

Notes:

^a Cost includes land acquisition and legal/administrative costs for institutional controls.

^b Includes construction engineering and management (6% of direct capital costs); construction quality control activities (by contractor); and construction quality assurance activities such as surveys, confirmation sediment sampling, and water quality monitoring.

^c Includes project management during design and construction (5% of direct capital costs) and estimated cost of removal design.

^d Contingency based on 30% of subtotal direct capital costs.

^e Long-term monitoring costs assume 7 monitoring events over 30 years. Maintenance costs based on one (1) cap repair event affecting up to 15% of the cap area. Present value analysis based on a 5% net discount rate.

Table 5-3. Estimated Costs for Alternative 2.

Item	Estimated Cost
Land Acquisition and Institutional Control Implementation ^a	\$ 700,000
Mob/Demob/Site Prep	\$ 263,000
Bank Excavation and Disposal	\$ 740,000
Dredging and Disposal	\$ 386,000
Capping	\$ 1,240,000
Outfall Modifications	\$ 130,000
Debris Removal and Disposal	\$ 137,000
Construction Engineering, Management, and QA/QC ^b	\$ 816,000
Washington State Sales Tax	\$ 343,000
Design and Project Management ^c	\$ 716,000
Contingency ^d	\$ 920,000
Long-Term Operation & Maintenance (30-yr Present Worth) ^e	\$ 480,000
Total	\$ 6,900,000

Notes:

^a Cost includes land acquisition and legal/administrative costs for institutional controls.

^b Includes construction engineering and management (6% of direct capital costs); construction quality control activities (by contractor); and construction quality assurance activities such as surveys, confirmation sediment sampling, and water quality monitoring.

^c Includes project management during design and construction (5% of direct capital costs) and estimated cost of removal design.

^d Contingency based on 30% of subtotal direct capital costs.

^e Long-term monitoring costs assume 7 monitoring events over 30 years. Maintenance costs based on one (1) cap repair event affecting up to 15% of the cap area. Present value analysis based on a 5% net discount rate.

Table 5-4. Estimated Costs for Alternative 3.

Item	Estimated Cost
Institutional Control Implementation ^a	\$ 100,000
Mob/Demob/Site Prep	\$ 328,000
Bank Excavation and Disposal	\$ 245,000
Dredging and Disposal	\$ 2,178,000
Capping	\$ 1,079,000
Outfall Modifications	\$ 130,000
Debris Removal and Disposal	\$ 163,000
Construction Engineering, Management, and QA/QC ^b	\$ 1,142,000
Washington State Sales Tax	\$ 484,000
Design and Project Management ^c	\$ 906,000
Contingency ^d	\$ 1,299,000
Long-Term Operation & Maintenance (30-yr Present Worth) ^e	\$ 660,000
Total	\$ 8,700,000

Notes:

^a Cost includes land acquisition and legal/administrative costs for institutional controls.

^b Includes construction engineering and management (6% of direct capital costs); construction quality control activities (by contractor); and construction quality assurance activities such as surveys, confirmation sediment sampling, and water quality monitoring.

^c Includes project management during design and construction (5% of direct capital costs) and estimated cost of removal design.

^d Contingency based on 30% of subtotal direct capital costs.

^e Long-term monitoring costs assume 7 monitoring events over 30 years. Maintenance costs based on four (4) cap repair events affecting up to 15% of the cap area. Present value analysis based on a 5% net discount rate.

Table 5-5. Estimated Costs for Alternative 4.

Item	Estimated Cost
Institutional Control Implementation ^a	\$ 100,000
Mob/Demob/Site Prep	\$ 328,000
Bank Excavation and Disposal	\$ 327,000
Dredging and Disposal	\$ 3,140,000
Capping	\$ 1,489,000
Outfall Modifications	\$ 130,000
Debris Removal and Disposal	\$ 163,000
Construction Engineering, Management, and QA/QC ^b	\$ 1,429,000
Washington State Sales Tax	\$ 647,000
Design and Project Management ^c	\$ 1,008,000
Contingency ^d	\$ 1,735,000
Long-Term Operation & Maintenance (30-yr Present Worth) ^e	\$ 660,000
Total	\$ 11,200,000

Notes:

^a Cost includes land acquisition and legal/administrative costs for institutional controls.

^b Includes construction engineering and management (6% of direct capital costs); construction quality control activities (by contractor); and construction quality assurance activities such as surveys, confirmation sediment sampling, and water quality monitoring.

^c Includes project management during design and construction (5% of direct capital costs) and estimated cost of removal design.

^d Contingency based on 30% of subtotal direct capital costs.

^e Long-term monitoring costs assume 7 monitoring events over 30 years. Maintenance costs based on four (4) cap repair events affecting up to 15% of the cap area. Present value analysis based on a 5% net discount rate.

Table 6-1. Applicable or Relevant and Appropriate Requirements.

Source	Requirement
Washington State Model Toxics Control Act (WAC 173-340-440)	These regulations are applicable to establishing institutional controls for capping. Each alternative would comply with these requirements by implementing appropriate institutional controls in capped areas.
Federal Water Pollution Control Act/ Clean Water Act (CWA) (33 USC 1251-1376; 33 CFR 320-330; 40 CFR 230-231)	These regulations establish the basic structure for regulating discharges of pollutants into the waters of the United States. Section 404 regulates the discharge of dredged material or fill into navigable waters. Section 401 requires water quality certification for such activities. The implementing regulations of these laws are applicable to sediment dredging and capping actions. Each alternative would comply with these regulations through design elements to avoid or minimize adverse effects, the implementation of best management practices, and a water quality monitoring program.
Washington State Water Quality Standards for Surface Waters (WAC 173-201A)	Standards for the protection of surface water quality have been established in Washington State. Acute marine criteria are anticipated to be relevant and appropriate requirements for discharge to marine surface water during sediment dredging and capping. Each alternative would comply with these regulations through the implementation of best management practices and a water quality monitoring program.
Washington State Sediment Management Standards (WAC 173-204)	Chemical concentration and biological effects standards are established for Puget Sound sediments and are applicable to each alternative. For each alternative, chemical concentrations in surface sediment within the removal boundary will be below the SQS following construction.
Construction in State Waters, Hydraulic Code Rules (RCW 77.55; WAC 220-110)	Hydraulic code rules for construction projects in state waters have been established for the protection of fish and shellfish, and are applicable to Slip 4 construction activities. Each alternative would comply with the substantive requirements of these regulations by implementing best management practices for the protection of fish and shellfish, as recommended by the Washington Department of Fish and Wildlife.
Federal Endangered Species Act of 1973 (16 USC 1531 et seq.; 50 CFR 216-226; 50 CFR 402)	These regulations are applicable to any actions performed at this site as this area is potential habitat for threatened and/or endangered species. A biological assessment will be conducted in conjunction with the removal design documents in consultation with NOAA Fisheries and USFWS. Each alternative is expected to comply with the substantive requirements of the Act through design elements to avoid or minimize adverse effects, and implementing best management practices and conservation measures as recommended by NOAA Fisheries and USFWS.
Resource Conservation and Recovery Act [40 CFR 260 - 268]	Dredged/excavated material may be subject to RCRA regulations if it contained a listed waste, or if it displays a hazardous waste characteristic, for example by the Toxicity Characteristic Leaching Procedure (TCLP). RCRA regulations may potentially be ARARs for the storage, treatment, and disposal of the dredged/excavated material unless an exemption applies. Based on site-specific information, it is likely that none of the sediments or soils meet the RCRA definition of hazardous waste.

Table 6-1 (continued). Applicable or Relevant and Appropriate Requirements.

Source	Requirement
Toxic Substances Control Act (TSCA) (40 CFR 761)	<p>This regulation is applicable to excavated or dredged materials containing PCBs. Each alternative would comply with TSCA by disposing all soils and sediments with total PCB concentrations greater than 50 mg/kg at a TSCA landfill.</p> <p>Disposal of soils and sediments with total PCB concentrations less than 50 mg/kg will follow the substantive requirements of 40 CFR 761.61, cleanup and disposal requirements for PCB remediation waste. Material meeting the definition of PCB remediation waste (761.3) would be disposed of using the three options under 761.61 (self-implementing option; performance-based option, and a risk-based option). The risk-based option under 761.61(c) would be expected to be selected at this site, and it may incorporate the requirements of the self-implementing option. If so, then PCB remediation wastes containing less than 50 mg/kg are allowed to be disposed of at non-TSCA municipal or solid waste landfills.</p>
Essential Fish Habitat (EFH) provisions of the Magnuson-Stevens Fishery Conservation and Management Act (50 CFR 600)	<p>This act identifies and protects important habitats of federally managed marine and anadromous fish species. This act is relevant and appropriate to cleanup actions at Slip 4. EPA makes a determination about whether a proposed action may adversely affect EFH.</p>
US Fish and Wildlife Coordination Act. (16 USC 661-667e)	<p>This statute establishes criteria to protect fish and wildlife that could be affected by proposed or authorized federal projects involving "impounding, diverting, or controlling waters." This act is relevant and appropriate to cleanup actions at Slip 4. EPA will consult with the U.S. Fish and Wildlife Service and the Washington Department of Fish and Wildlife regarding the potential effects of the project on fish and wildlife and identify measures that would mitigate those impacts. Also, the statute requires that adequate provision be made for the conservation, maintenance, and management of fish and wildlife resources and their habitats.</p> <p>The ESA consultation described above will also satisfy the substantive requirements of the Fish and Wildlife Coordination Act.</p>
Migratory Bird Treaty Act (16 USC 703-712)	<p>Governs the taking, killing, possession, transportation, and importation of migratory birds, their eggs, parts and nests. This act is applicable to cleanup actions at Slip 4. Actions will be taken as needed to protect habitat for migratory birds, and avoid disturbances of their nests and eggs.</p>
Rivers and Harbors Appropriations Act (33 USC 403; 33 CFR 320 - 323)	<p>Section 10 of this act establishes permit requirements for activities that may obstruct or alter a navigable waterway. Activities that could impede navigation and commerce are prohibited. These substantive permit requirements are anticipated to be applicable to dredging and capping actions that may affect the navigable portions of the waterway. EPA will evaluate compliance with these regulations concurrently with their CWA 404 evaluation.</p>

Table 6-1 (continued). Applicable or Relevant and Appropriate Requirements.

Source	Requirement
<p>Washington Solid Waste Management Act (RCW 70.95)</p> <p>Solid Waste Handling Standards (WAC 173-350)</p>	<p>These regulations are applicable to the disposal of non-hazardous waste generated during remedial activities. These standards set minimum functional performance standards for the proper handling and disposal of solid waste, identifies functions necessary to assure effective solid waste handling programs at both the state and local level, and follows priorities for the management of solid waste.</p> <p>Because the disposal of the dredged sediments and debris will take place in a permitted solid waste landfill that is outside the site boundaries, both substantive and administrative requirements of applicable regulations must be met for this activity.</p> <p>The offsite rule (40 CFR 302.440) of the NCP requires that solid and hazardous waste offsite landfills to which CERCLA hazardous substances are being sent must be acceptable to EPA. The project specifications will require the contractor to obtain EPA approval of the proposed disposal facility.</p> <p>In practical terms, the requirements for disposal of dredged sediments will be found in the permit of the landfill that agrees to accept the waste. For example, the Roosevelt Regional Landfill's permit allows it to accept sediments that, while dewatered, do not need to pass the paint filter test (to limit free-draining liquids) before disposal.</p>
<p>Washington Dangerous Waste Regulations (WAC 173-303)</p>	<p>These state rules regulate the generation, handling, storage, and disposal of dangerous waste. Dredged material and debris would be evaluated for dangerous waste designation in accordance with these regulations.</p> <p>Because the disposal of the dredged sediments and debris will take place in a permitted solid waste landfill that is outside the site boundaries, both substantive and administrative requirements of applicable regulations must be met for this activity.</p>
<p>Executive Order for Floodplain Management (Executive Order 11988; 40 CFR Part 6, App. A)</p> <p>FEMA National Flood Insurance Program Regulations (44CFR 60.3 (d)(3))</p>	<p>Executive Order 11988 requires measures to reduce the risks of flood loss, minimize impact of floods, and restore and preserve the natural and beneficial values of floodplains. The NFIP regulations prohibit encroachments, including fill, within the adopted regulatory floodway unless engineering analyses demonstrate that the proposed encroachment would not increase flood levels. Each alternative meets the requirements of the Executive Order. EPA's sediment guidance document (USEPA 2005b) states that although not ARARs, the Agency normally follows executive orders as a matter of policy. The dredge and fill activities in Slip 4 are outside the floodway limits, and therefore the net filling under Alternatives 1 and 2 is allowable under the NFIP regulations.</p>
<p>Native American Graves Protection and Repatriation Act (NAGPRA) (25 USC 3001 et seq.; 43 CFR 10)</p>	<p>NAGPRA and implementing regulations are intended to protect Native American graves from desecration. These regulations are potentially applicable. Excavation or dredging must cease if Native American burials or cultural items are discovered.</p>
<p>American Indian Religious Freedom Act (42 USC 1996 et seq.)</p>	<p>These regulations are potentially applicable. Excavation or dredging must cease if Native American sacred religious sites, burials, or cultural items are discovered.</p>

Table 6-1 (continued). Applicable or Relevant and Appropriate Requirements.

Source	Requirement
National Historic Preservation Act (16 USC 470f; 36 CFR 800)	These regulations are potentially applicable. If Native American or other cultural materials are discovered as part of the dredging or excavation, alternatives must be evaluated to avoid, minimize, or mitigate the impact.
Archaeological Resources Protection Act (16 USC 470 et seq.; 43 CFR 7)	These regulations are potentially applicable. Excavation or dredging must cease if archaeological resources are discovered.
Washington State Shoreline Management Act (RCW 90.58) Shoreline Management KCC Title 25	KCC Title 25 regulations implement the State Shoreline Management Act, and are applicable to all building, excavation, dredging, and filling within 200 feet of regulated shorelines. May require removal of illegal fill placed after 1972. Changes to the shoreline resulting from cleanup will be evaluated in design.
Critical Areas KCC Title 21A.24	State Law (the Growth Management Act) requires local governments to develop regulations to protect critical areas, but the content of these regulations is left to local government discretion – these ordinances are not subject to State approval. These will be addressed as To Be Considered for the Slip 4 CERCLA cleanup.

Table 6-2. Habitat Acres by Elevation Range.

Habitat Elevation Range (ft MLLW)	Existing Conditions (Acres)	Historically Permitted Conditions ^a (Acres)	Alternative 1 (Acres)	Alternative 2 (Acres)	Alternative 3 (Acres)	Alternative 4 (Acres)
Upland (+12 to TOB)						
Riparian (+12 to top of bank)	0.21	0.21	0.23	0.21	0.20	0.20
Aquatic (Below +12)						
Upper Intertidal (+12 to +4)	0.33	0.32	1.15	0.81	0.63	0.57
Lower Intertidal (+4 to -4)	1.54	1.30	1.13	1.59	1.26	1.29
Shallow Subtidal (-4 to -10)	0.79	0.71	1.15	1.05	0.43	0.42
Sublittoral (Deeper than -10)	0.71	1.05	0.00	0.00	1.07	1.10
Total Aquatic	3.38	3.38	3.43	3.46	3.38	3.38
Project Total						
Total Acreage	3.59	3.59	3.66	3.67	3.58	3.58

^a Historically permitted conditions inferred from permitted 1981 dredge prism, and existing topography outside of dredge prism.

Table 6-3. Net Changes in Habitat Acres by Elevation Range.

Habitat Elevation Range (ft MLLW)	Alternative 1 (Acres)	Alternative 2 (Acres)	Alternative 3 (Acres)	Alternative 4 (Acres)
Upland (+12 to Top of Bank)				
Riparian (+12 to top of bank)	0.01	0.00	-0.01	-0.01
Aquatic (Below +12)				
Upper Intertidal (+12 to +4)	0.82	0.49	0.30	0.24
Lower Intertidal (+4 to -4)	-0.41	0.05	-0.29	-0.26
Shallow Subtidal (-4 to -10)	0.35	0.26	-0.37	-0.37
Sublittoral (Deeper than -10)	-0.71	-0.71	0.36	0.39
Total Aquatic	0.06	0.08	0.00	0.00
Project Total				
Total Acreage	0.07	0.07	-0.01	-0.01

Notes:

Changes in acreages are relative to existing conditions.

Table 6-4. Summary of Comparative Analysis.

Criterion	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Effectiveness				
Overall protection of human health and environment	Protective.	Protective.	Protective.	Protective.
Achievement of RAOs	Achieves the RAO.	Achieves the RAO.	Achieves the RAO.	Achieves the RAO.
Compliance With ARARs	Complies with ARARs. Surface sediment PCB concentrations will be below the SQS following the removal action. Complies with CWA 404 and ESA requirements. Expands shallow subtidal, intertidal, and total aquatic habitat. Landfill disposal complies with federal and state regulations.	Complies with ARARs. Surface sediment PCB concentrations will be below the SQS following the removal action. Complies with CWA 404 and ESA requirements. Expands shallow subtidal, intertidal, and total aquatic habitat. Landfill disposal complies with federal and state regulations.	Complies with ARARs. Surface sediment PCB concentrations will be below the SQS following the removal action. Complies with CWA 404 and ESA requirements. No net loss of aquatic habitat. Decreases shallow subtidal and intertidal habitat to historically permitted conditions. Requires armoring in remaining intertidal areas, which may result in a less desirable substrate. Landfill disposal complies with federal and state regulations.	Complies with ARARs. Surface sediment PCB concentrations will be below the SQS following the removal action. Complies with CWA 404 and ESA requirements. No net loss of aquatic habitat. Decreases shallow subtidal and intertidal habitat to historically permitted conditions. Requires armoring in remaining intertidal areas, which may result in a less desirable substrate. Landfill disposal complies with federal and state regulations.
Reduction of toxicity, mobility, or volume through treatment	Does not include treatment.	Does not include treatment.	Does not include treatment.	Does not include treatment.

Table 6-4 (continued). Summary of Comparative Analysis.

Criterion	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Long-term effectiveness and permanence	<p>Effective and permanent.</p> <p>Most contaminated material would remain in place, effectively contained by engineered caps. Caps require long-term monitoring and potentially maintenance.</p> <p>Low erosion potential. However, consequences of cap erosion at head of slip could be greater than Alternatives 2, 3, or 4.</p> <p>Monitoring and periodic reviews would verify long-term effectiveness and permanence. Land use restrictions would minimize potential for cap disturbance.</p>	<p>Effective and permanent.</p> <p>Sediments with the highest concentrations of contaminants would be permanently removed.</p> <p>Remaining contaminated material would be effectively contained by engineered caps. Caps require long-term monitoring and potentially maintenance.</p> <p>Low erosion potential.</p> <p>Monitoring and periodic reviews would verify long-term effectiveness and permanence. Land use restrictions would minimize potential for cap disturbance.</p>	<p>Effective and permanent.</p> <p>Sediments with the highest concentrations of contaminants would be permanently removed. Additional contaminated sediments in the inner berth area would be removed.</p> <p>Remaining contaminated material would be effectively contained by engineered caps. Caps require long-term monitoring and potentially maintenance.</p> <p>Greater erosion potential and potentially greater cap maintenance requirements than Alternatives 1 and 2 due to navigation uses.</p> <p>Monitoring and periodic reviews would verify long-term effectiveness and permanence. Land use restrictions would minimize potential for cap disturbance.</p>	<p>Effective and permanent.</p> <p>Most contaminated material would be permanently removed from the slip.</p> <p>Remaining contaminated material would be effectively contained by engineered caps. Caps require long-term monitoring and potentially maintenance.</p> <p>Greater erosion potential than Alternatives 1 and 2 due to navigation uses.</p> <p>Potentially less cap maintenance requirements than Alternative 3, since backfill in many areas would not be considered a cap.</p> <p>Monitoring and periodic reviews would verify long-term effectiveness and permanence. Land use restrictions would minimize potential for cap disturbance.</p>

Table 6-4 (continued). Summary of Comparative Analysis.

Criterion	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Short-term effectiveness	<p>Achieves RAOs immediately following construction. No significant risks to workers or the community.</p> <p>Limited excavation (8,100 cy). Most excavation would be completed in-the-dry, and surrounding areas would be capped. Low potential for water quality impacts or releases of material into surrounding areas.</p> <p>Short-term impacts to water quality would be managed through engineering controls and BMPs.</p>	<p>Achieves RAOs immediately following construction. No significant risks to workers or the community.</p> <p>Limited excavation and dredging (14,000 cy). Roughly two-thirds of the material would be excavated in-the-dry, and areas surrounding all excavation or dredging would be capped. Low potential for water quality impacts or releases of material into surrounding areas.</p> <p>Short-term impacts to water quality would be managed through engineering controls and BMPs.</p>	<p>Achieves RAOs immediately following construction. No significant risks to workers or the community.</p> <p>Substantial amount of excavation and dredging (27,000 cy). Dredging would extend to removal area boundaries. Potential releases of material into surrounding areas would be minimized through BMPs and managed with contingency actions.</p> <p>Some potential need for extension of in-water work period to complete in one construction season – this would be coordinated with agencies.</p> <p>Short-term impacts to water quality would be managed through engineering controls and BMPs. Short-term impacts to water quality would be of greater duration as compared to Alternatives 1 and 2.</p>	<p>Achieves RAOs immediately following construction. No significant risks to workers or the community.</p> <p>Greatest amount of excavation and dredging (40,000 cy). Dredging would extend to removal area boundaries. Potential releases of material into surrounding areas would be minimized through BMPs and managed with contingency actions.</p> <p>Some potential need for extension of in-water work period to complete in one construction season – this would be coordinated with agencies.</p> <p>Short-term impacts to water quality would be managed through engineering controls and BMPs.</p> <p>Short-term impacts to water quality would be of greatest duration.</p>

Table 6-4 (continued). Summary of Comparative Analysis.

Criterion	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Implementability				
Technical feasibility	Readily and reliably implemented.	Readily and reliably implemented.	Readily and reliably implemented. Actions in the inner berth area would require special consideration of design, monitoring, and construction elements to attain SQS in the inner berth, remove sediments under the pier, and cap under the pier. Similar care in design, monitoring, and construction would be needed to address potential fugitive dredging residuals affecting surrounding areas.	Readily and reliably implemented. Actions in the inner berth area would require special consideration of design, monitoring, and construction elements to attain SQS in the inner berth, remove sediments under the pier, and cap under the pier. Similar care in design, monitoring, and construction would be needed to address potential fugitive dredging residuals affecting surrounding areas.
Availability	Services, equipment, and materials readily available.	Services, equipment, and materials readily available.	Services, equipment, and materials readily available.	Services, equipment, and materials readily available.
Administrative feasibility	City purchase of land is feasible. The work will be completed on land owned by the City, First South Properties, and potentially The Boeing Company. Access agreements are anticipated to be required for the work. Institutional controls are required to protect the cap, including deed restrictions if the property is sold.	City purchase of land is feasible. The work will be completed on land owned by the City, First South Properties, and potentially The Boeing Company. Access agreements are anticipated to be required for the work. Institutional controls are required to protect the cap, including deed restrictions if the property is sold.	The work will be completed on land owned by Crowley Marine Services, First South Properties, and potentially The Boeing Company. Access agreements are anticipated to be required for the work. Institutional controls are required to protect the cap, including deed restrictions if the property is sold.	The work will be completed on land owned by Crowley Marine Services, First South Properties, and potentially The Boeing Company. Access agreements are anticipated to be required for the work. Institutional controls are required to protect the cap, including deed restrictions if the property is sold.
Total Cost¹	\$6,000,000²	\$6,900,000²	\$8,700,000	\$11,200,000

Notes:

¹ Net Present Value analysis based on 2007 year 0, and 5% net discount rate. Long-term monitoring costs based on seven events over 30 years. Maintenance costs based on assumed cap repairs associated with erosion potential.

² Costs for Alternatives 1 and 2 include cost of land acquisition for implementation.

Lower Duwamish Waterway Slip 4 Early Action Area

Appendix A Revised Draft Technical Memorandum on Proposed Boundary of the Removal Action



LOWER DUWAMISH WATERWAY SLIP 4 EARLY ACTION AREA

REVISED DRAFT TECHNICAL MEMORANDUM ON PROPOSED BOUNDARY OF THE REMOVAL ACTION

Submitted to

U.S. Environmental Protection Agency, Region 10
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Seattle, WA 98101

Submitted by

City of Seattle
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January 14, 2005

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LIST OF ACRONYMS

2LAET	second lowest apparent effects threshold
AET	apparent effects threshold
AOC	Administrative Order on Consent
BEHP	bis(2-ethylhexyl)phthalate
CFR	Code of Federal Regulations
CSL	Cleanup Screening Levels
dw	dry weight
Ecology	Washington Department of Ecology
EE/CA	engineering evaluation and cost analysis
EF	exceedance factor
EPA	U.S. Environmental Protection Agency
FS	feasibility study
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
LAET	lowest apparent effects threshold
MLLW	mean lower low water
MTCA	Model Toxics Control Act
NAD	North American Datum
NOAA	National Oceanic and Atmospheric Administration
OC	organic carbon
PCBs	polychlorinated biphenyls
QC	quality control
RI	remedial investigation
SAP	sampling and analysis plan
SMS	Sediment Management Standards
SOW	Statement of Work
SQS	Sediment Quality Standard
TOC	total organic carbon
WAC	Washington Administrative Code

1 INTRODUCTION

This technical memorandum presents the proposed boundary for the Slip 4 Early Action Area removal action¹. Slip 4 is located approximately 2.8 miles from the mouth of the Duwamish River in Seattle, WA (Figure 1). The City of Seattle and King County are performing the Slip 4 characterization and boundary definition work under Tasks 9 and 10 of the existing Administrative Order on Consent (AOC) Statement of Work (SOW) for the Lower Duwamish Waterway (LDW), and per requirements of the Slip 4 Revised Work Plan (Integral 2004b).

The proposed removal action boundary for the Slip 4 Early Action Area is presented in this memorandum to facilitate discussions on the boundary among all stakeholders prior to preparation of the engineering evaluation and cost analysis (EE/CA). This memorandum relies on data presented in SEA (2004) and Integral (2004a). The EE/CA will contain more detailed information than is presented in this memorandum, and will undergo a formal public review. The final boundary will be selected by the U.S. Environmental Protection Agency (EPA) in a formal decision document (the Action Memorandum).

1.1 PROJECT BACKGROUND

The Lower Duwamish Waterway (LDW) in Seattle, WA, was added to EPA's National Priorities List (aka Superfund) in September 2001 because of chemical contaminants in sediments. The key parties involved in the LDW site are the Lower Duwamish Waterway Group (LDWG) (comprised of the City of Seattle, King County, the Port of Seattle, and The Boeing Company), EPA, and Washington Department of Ecology (Ecology). The LDWG is voluntarily conducting the LDW remedial investigation and feasibility study (RI/FS).

The first phase of the LDW RI used existing data to evaluate the nature and extent of chemical distributions in LDW sediments and presented preliminary risk estimates (Windward 2003b). Information obtained during the LDW Phase 1 RI was used to identify locations in the LDW that could be candidates for early cleanup action (Windward 2003a,b). Slip 4 was identified as a candidate early action site by EPA and Ecology (Windward 2003a) based primarily on elevated concentrations of polychlorinated biphenyls (PCBs). Compared to a remedial action (which typically

¹ EPA and Ecology (Windward 2003a) use the term "early action" to refer to short-term cleanups that are called "removal actions" under CERCLA, "interim actions" under MTCA, or "partial cleanup actions" under the Washington State Sediment Management Standards (SMS). This document uses the term "removal action."

occurs after the RI/FS, proposed plan, and Record of Decision have been prepared), removal actions are generally defined as short-term, quickly implemented actions designed to eliminate or minimize a known significant risk from Superfund sites.

The process used by EPA and Ecology to identify early action sites followed both the National Contingency Plan, which requires that threats to human or animal populations, sensitive ecosystems or other significant factors affecting the health or welfare of the public or environment be considered when identifying removal actions (40 CFR 300.415), and the Washington State Model Toxics Control Act (MTCA). MTCA defines interim actions as "a remedial action that is technically necessary to reduce a threat to human health or the environment by eliminating or substantially reducing one or more pathways for exposure to a hazardous substance at a facility" (WAC 173-340-430) (Windward 2003a).

Existing information for the Slip 4 Early Action Area was compiled by SEA (2004). That report included descriptions of the physical environment, potential chemical sources, sediment data collected between 1990 and 1998, and existing habitat and human uses of the slip. SEA (2004) also identified data gaps to be filled prior to the identification of the boundary for an early removal action of contaminated sediments. Additional sediment and bank chemistry data were collected in March and July 2004 (Integral 2004c,d,e; Landau 2004) to address these data gaps and were reported by Integral (2004a). These data form the basis for the proposed removal action boundary identified in this report.

This memorandum evaluates available Slip 4 data and identifies the proposed boundary of the Slip 4 Early Action Area removal action. Minor modifications to this boundary may be made in response to engineering constraints that will be identified during the upcoming EE/CA. The removal action boundary may be refined in the EE/CA. The EE/CA process includes a formal public comment period. EPA will then document and approve the removal action boundary in an Action Memorandum, which is EPA's primary decision document for a removal response.

Areas in the LDW outside of the boundary will continue to be evaluated by the LDWG, EPA, and Ecology under the LDW RI/FS. The LDW RI/FS will include an ecological and human health risk assessment to evaluate potential risks to human health and the environment posed by the LDW site. Ecology will continue to evaluate upland sites adjacent to the waterway and within the Slip 4 drainage basin for source control or other action, as appropriate.

1.2 REPORT ORGANIZATION

Section 2 of this report briefly summarizes the historic and recent sediment chemistry data that were considered for use in determining the removal action boundary. Section 3 presents the proposed boundary for the removal action and describes the process used to identify the boundary. Finally, references are listed in Section 4.

2 SUMMARY OF SEDIMENT CHARACTERIZATION RESULTS

As required by the work plan (Integral 2004b), all available data were considered for development of the boundary for the Slip 4 Early Action Area removal action. All sediment chemistry data collected in Slip 4 have been presented in detail in earlier reports². SEA (2004) described data collected from 1990 – 1998, and Integral (2004a) described data collected in 2004. No data were collected between 1998 and 2004. Both the historic and 2004 data are briefly summarized below and are depicted in Figures 2 – 5.

For characterization purposes and to assist in data interpretation, results are compared to Washington State Sediment Management Standards (SMS) numerical criteria for sediment quality standards (SQS) and cleanup screening levels (CSL) (WAC 173-204 (Table 1)³. These values provide a basis for identifying the aerial extent of sediments that may pose a risk to some ecological receptors, and are thus useful for identifying sediments that may pose unacceptable risks. Sediments that are not identified as requiring removal using the SMS will continue to be evaluated for risks to both human health and other ecological receptors by the LDW RI/FS human health and ecological baseline risk assessment processes.

Sediments with chemical concentrations less than the SQS are expected to have no adverse effects on biological resources in sediments. An exceedance of the SQS numerical criteria indicates the potential for minor adverse biological effects or toxicity; and biological testing may be used to confirm that minor adverse effects actually occur. The CSL is defined as the maximum allowed chemical concentration and level of biological effects permissible at a cleanup site to be achieved 10 years after cleanup is completed. The CSL is greater than or equal to the SQS and represents a higher level of risk to benthic organisms than SQS levels.

The EE/CA that will be prepared for Slip 4 will contain more detailed information than is presented in this document, including a streamlined risk evaluation for human health and ecological risks.

² Only sediment chemistry data are available for Slip 4. The only biological data were collected in areas that have since been dredged (SEA 2004).

³ The minimum total organic carbon (TOC) concentration for TOC normalization and comparison to the SMS is 0.2% (Michelsen 1992). Chemical concentrations in the few samples with TOC < 0.2% are compared to dry-weight apparent effects threshold (AET) values instead of TOC-normalized SMS values.

2.1 SURFACE SEDIMENT

2.1.1 1990 – 1998 Data

Surface sediment chemistry data were collected from 41 locations in Slip 4 from 1990 to 1998 by a number of investigations. PCBs data are compared to SMS criteria and summarized in Figure 2. [Note that some of the data generated by the National Oceanic and Atmospheric Administration (NOAA) have been determined to be potentially biased high due to the analytical methodology (not sampling) bias (Araki 2004)⁴. Affected PCB data with potential high bias include all samples beginning with “EIT” or “EST” except for EIT-067, EIT-068, EST-171, EST-172, EST-173, and EST-175.] All chemical concentrations greater than the SQS (i.e., chemicals potentially having adverse impacts on biological communities in sediments) are listed in Table 2.

The historic data confirmed that PCBs are the contaminant of primary concern in Slip 4 surface sediments⁵. PCBs exceeded the SQS at nearly all sampling locations; over half the locations exceeded the PCB CSL. The highest PCB concentrations were at the head of the slip, and concentrations decreased toward the mouth. In addition to PCBs, metals and polycyclic aromatic hydrocarbons (PAHs) exceeded SQS values in samples located in the vicinity of the outfalls at the head of the slip (Table 2). Finally, bis(2-ethylhexyl)phthalate (BEHP) also exceeded the SQS and the CSL at some stations.

2.1.2 2004 Data

PCB Aroclors and mercury were analyzed in surface sediment samples collected at 29 locations (plus 2 field replicates), one intertidal composite location, and 6 bank sample locations in 2004. The other SMS analytes were analyzed in a subset of samples from areas likely to be outside the boundary, as well as at a quality control (QC) station in the upper portion of the slip. [The rationale for selection of samples for SMS analysis is provided in Integral (2004e).] Chemicals with SQS and CSL exceedances in surface and bank samples are listed in Table 3 and shown in Figures 3 and 4.

In comparison to the historical data for surface sediments, PCB concentrations in 2004 were substantially lower than concentrations found in the period 1990 – 1998. PCB concentrations in 2004 exceeded the SQS at six stations (Figure 3). CSL exceedances

⁴ As stated by Araki (2004):

“Results that are less than 100 µg/kg are considered estimates and should be “J” qualified because they may have a large potential negative bias (i.e., PCB concentrations may be underestimated).

Results between 100 and 600 µg/kg are considered usable without qualification. However, there is still a potential positive bias which may be associated with these results and cannot be confirmed.

Results that are greater than 600 µg/kg are considered estimates and should be “J” qualified because they may have a potential positive bias (i.e., PCB concentrations may be overestimated). Depending upon the PCB congener this potential systematic positive bias ranges from 5% to 9%.”

⁵ Of the 41 historic sampling locations, there were only two locations (SL4-10 and SL4-12; Figure 2) where detected chemicals other than PCBs exceeded the SQS, but PCBs did not exceed the SQS (Table 2).

were confined to three stations at the head of the slip and the intertidal composite sample located along the southern end of First South Properties. Total PCBs at the remaining 20 surface sediment stations were below the SQS.

For the subset of 2004 samples that were analyzed for other SMS analytes, eight subtidal samples were analyzed for all SMS organic compounds; four of these eight samples were also analyzed for all SMS metals (Figure 4) (Integral 2004e). Two additional samples (i.e., samples SG06 and SG06FR) were analyzed for all SMS organics and metals because they were the project's field quality control (QC) samples. Intertidal station IC01 was also analyzed for all SMS analytes. Except for the field QC samples, only one of these locations (SG16) had detected chemicals other than PCBs at concentrations greater than the SQS (however, PCBs also exceeded the SQS at this location) (Table 3, Figure 3). At Station SG16, BEHP and phenol, as well as PCBs, were slightly above the SQS. In the field QC samples [SG06 and SG06FR(SG41S)], two organic chemicals, as well as PCBs, were greater than the SQS or CSL (Figure 4). No other metals or organic chemicals exceeded the SQS in Slip 4 surface sediment samples collected in 2004.

2.2 SUBSURFACE SEDIMENT

2.2.1 1990 – 1998 Data

The only historic sediment core data for Slip 4 were collected in 1990 (Landau 1990, SEA 2004). As in surface sediments, PCBs were the contaminant with the most frequent SQS exceedances; these results are presented in Figure 5. Only two detected chemicals other than PCBs (i.e., acenaphthene and fluoranthene at SL4-06A and SL4-09A) exceeded the SQS in subsurface sediments below 2 feet (SQS exceedance factors 1.06 – 2.88) [Figure 5-14 in SEA (2004)]. The maximum depth of PCB SQS exceedances ranged from 4 feet to greater than 9 feet (Figure 5). CSL exceedances below 4 feet were observed in only 2 of the 10 cores (i.e., Stations SL4-6A and SL4-10A). At both locations with CSL exceedances below 4 feet, PCBs were the only detected chemical exceeding the CSL at depths greater than 4 feet, and the maximum depth of PCBs exceeding the CSL was greater than 8 – 9 feet. In general, PCB concentrations tended to decrease with depth (based on composited samples from 1.5 to 2-foot core intervals).

2.2.2 2004 Data

Of the 11 stations where subsurface cores were collected in 2004, samples from nine stations were analyzed by either the City of Seattle/King County or The Boeing Company. Samples from Stations SC08 and SC10 remain archived. PCB concentrations from these nine stations are also shown in Figure 5. Six of the nine cores that were analyzed contained one or more intervals with PCBs greater than the CSL. At these stations, CSL exceedances commonly occurred to a depth of 4 or 6 feet. At most locations, no SQS exceedances occurred below 4 – 6 feet, although CSL exceedances occurred in the 8- to 10-foot interval at Station SC-02 and in the 6- to 8-foot interval at

Station SC-03. The depth of sediments exceeding SQS was bounded in all cores except SC-02. An archived sample from the 10- to 12-foot interval at SC-02 may be analyzed, if needed, for design purposes.

Other detected chemicals that exceeded the SQS or CSL in subsurface sediments were limited to mercury (seven samples with exceedances) and silver (one sample) (Table 4). All metals exceedances were in samples that also had PCBs greater than the SQS or CSL except for the 6- to 8-foot interval at Station SC04. Other than PCBs, there were no detected organic chemicals in subsurface sediment samples that exceeded the SQS or CSL (Integral 2004a).

2.3 BANK SAMPLES

Six bank samples were collected at +10 feet mean lower low water (MLLW)⁶ along unarmored sections of the Slip 4 shoreline and analyzed for PCB Aroclors and mercury. PCBs at four sampling locations along the southeast shoreline exceeded the SQS, and one station (BK06) exceeded the CSL (Figure 3). Previous upland investigations have characterized the stratigraphy of soils near the Slip 4 embankments (Landau 1990). These soil borings indicate that fill material overlies native tideflat and river deposits. In the vicinity of the southeast Slip 4 shoreline, where bank samples exceeded SQS at +10 feet MLLW, the fill/native interface generally occurs at elevations ranging from +4 to +11 feet MLLW. Therefore, the bank samples collected in this investigation may represent fill material or some mixture of fill material and sedimentary deposits. Field observations by sampling personnel noted possible fill material in bank samples.

Intertidal sediments below the bank in the vicinity of Station BK06 (Station IC01) also contained PCBs at concentrations exceeding the CSL. Sediments exhibiting elevated PCBs in this localized intertidal area are likely being impacted by eroding fill from the bank.

2.4 COMPARISON OF HISTORIC AND 2004 DATA

When the surface PCB concentrations from 2004 are compared with historical data collected between 1990 and 1998, it is evident that PCB concentrations in surface sediments in many areas of the slip are less in 2004 than they were between 1990 and 1998 (Figures 2 and 3). In addition, the 2004 co-located surface (surface to 10 cm) and subsurface sample results can be compared (Figure 5). In all cases, total PCBs in the

⁶All elevations at Slip 4 are referenced to MLLW, a U.S. survey vertical datum, and are given in feet. Tidal elevations at Slip 4 range from extreme lows of approximately -4 feet MLLW to extreme highs of approximately +13 feet MLLW. The estimated top of bank elevation in Slip 4 is approximately +12 to +16 ft MLLW.

surface sample are less than the concentrations in the top interval (0-2 feet) of the co-located core. These decreasing PCB concentrations over time and throughout the slip may be the result of reduced PCB input due to source control, physical processes consistent with natural recovery (e.g., sedimentation, dispersion, dilution, bioturbation), or other factors occurring within Slip 4.

3 PROPOSED BOUNDARY IDENTIFICATION AND RATIONALE

The proposed boundary for the removal action at the Slip 4 Early Action Area is presented in this section along with the supporting rationale. This proposed boundary is preliminary and may be refined during the EE/CA. In addition, the vertical boundary for the removal action (i.e., the depth to which sediments may require remediation) is not defined as part of this memorandum, but will be determined during the EE/CA based on the removal alternatives, sediment characteristics, and engineering considerations. EPA will document and approve the removal action boundary in an Action Memorandum, which is EPA's primary decision document for a removal response.

In addition to presenting the removal action boundary, the EE/CA will include information on the site such as the nature and extent of existing sediment contamination; relevant physical, geological and biological conditions; and source control considerations. The EE/CA will include a streamlined risk evaluation for human health and ecological risks. It will also present potential cleanup technologies, evaluate cleanup alternatives and identify the preferred cleanup alternative for the removal action.

Areas in the LDW outside of the boundary will continue to be evaluated by the LDWG, EPA, and Ecology under the LDW RI/FS. The LDW RI/FS will include an ecological and human health risk assessment to evaluate potential risks to human health and the environment posed by the LDW site. Ecology will continue to evaluate upland sites adjacent to the waterway and within the Slip 4 drainage basin for source control or other action, as appropriate.

3.1 BOUNDARY DEFINITION CONSIDERATIONS

The boundary was identified after considering the following:

- The City of Seattle and King County are actively involved in source control efforts in the Slip 4 drainage basin. The boundary of the removal action reflects the area of Slip 4 that appears to have been impacted by one or more uncontrolled sources within this drainage basin.
- The proposed boundary is based on 2004 data. Comparison of historic (1990 – 1998) surface sediment data and 2004 data indicate that present-day surface sediments throughout the slip are substantially cleaner than those collected 6 to 14 years ago. This observation of reduced surface PCB concentrations in surface

- sediments is further supported by subsurface core data and comparisons of co-located surface and subsurface samples (Section 2.4).
- The overall approach for identifying the boundary compared surface sediment chemical concentrations to the Washington State SMS values (CSL and SQS). The approach focused on the areal extent of PCBs because the historical data (Table 2; Table 5-6 of SEA 2004) had shown that PCBs were the primary contaminant of concern. In the historical data set, only PCBs and BEHP exceeded the CSL at more than one station, and the distribution of PCB exceedances was greater than the distribution of BEHP exceedances. Analyses in 2004 focused on PCBs, but full-suite SMS analyses were also performed on a subset of samples to determine if other chemical exceedances exist outside of the PCB exceedance area.
 - The proposed boundary includes a section that crosses the slip and a section that follows the shoreline. The proposed boundary across the slip is generally based on exceedances of the PCB SQS value [12 mg/kg organic carbon (OC)] in surface (i.e., 0 – 10 cm) sediments. There were no CSL exceedances and only two slight SQS exceedances at one station outside of the proposed boundary (Figure 4). The proposed boundary across the slip is set outside of the bank areas that have elevated PCB concentrations. This boundary crosses the slip so that it abuts the area near the southwestern portion of the Crowley dock that was dredged in 1996. It includes the intertidal composite sample area with elevated PCBs. The proposed boundary along the shoreline is set at the face of the Crowley dock or the toe of the bank.
 - Banks with elevated PCB concentrations exist along the eastern shoreline of Slip 4 (Figure 3). The banks comprise eroding, low-bank bluffs and failing or dilapidated bulkheads. These bank deposits likely include fill material that may be a historic and/or ongoing source to Slip 4 sediment and are therefore considered candidates for source control or removal actions by Ecology. Ecology is moving forward to investigate the nature, extent, and source of this material and will oversee cleanup as needed. Because this fill material is being addressed by Ecology, areas above the toe of the bank or bulkhead are not included within the proposed removal action boundary.

The proposed removal boundary includes the inner half of Slip 4 (Figure 6). This area includes all surface sediments with chemical concentrations greater than the SQS except for one isolated station with minor SQS exceedances. Areas outside the proposed boundary will continue to be evaluated by the LDWG, EPA, and Ecology pursuant to the LDW RI/FS. A detailed Slip 4 map showing the topographic and bathymetric contours with the proposed removal boundary is included in Appendix A.

3.2 BOUNDARY ACROSS THE SLIP

The portion of the proposed boundary across the slip was drawn perpendicular to the shoreline beginning at the edge of the riprap on the northeastern edge of the property owned by The Boeing Company and extending across the slip to the Crowley pier. The edge of the riprap on Boeing property also coincides with a chain-link fence at the top of the bank that demarks the property line between First South Properties and Boeing. All but one 2004 surface sample in the outer half of the slip had PCB concentrations below the SQS. Station SG16 had a PCB concentration of 15.4 mg/kg OC (the PCB SQS is 12 mg/kg OC), and had very minor exceedances of the SQS values for phenol and BEHP (Figures 3 and 4). (The SQS exceedance factors for these two chemicals were 1.14 and 1.09, respectively.) It is also in an area that was dredged in 1996.

Two historical surface sampling stations (i.e., Stations EIT066 and SL4-11) located offshore of Boeing's riprap (Figure 2) exceeded the CSL for PCBs. These stations are not contained within the removal action boundary. Station EIT066 was sampled by NOAA in 1997. EPA has determined that the PCB data at station EIT066 are potentially biased high due to bias in the methodology (see Section 2.1.1) (Araki 2004). Data for Station SL4-11 were reported by Landau (1990). As shown on Figure 5, this area was resampled as part of the Slip 4 Early Action Area characterization in 2004 and found to contain both surface and subsurface sediment PCB concentrations below the SQS. Similarly, historical surface sampling Station DR-181, located offshore of Crowley, exceeded the CSL for PCBs. This area was also resampled in 2004 and surface sediment PCB concentrations were below the SQS.

3.3 SHORELINE BOUNDARY

The proposed removal action boundary around the shoreline of the upper half of Slip 4 was drawn to be either at the face of the Crowley pier or at the toe of the bank or bulkhead (Figure 6). "Toe of the bank" is defined as the elevation at which there is a well-defined increase in slope and a transition from relatively shallow slopes to oversteepened or unstable embankments. "Toe of the bulkhead" is the elevation at which the bulkhead intersects the groundline on the waterward side (i.e., mudline). The proposed boundary has been divided into five areas (see Figure 6). This division of areas reflects physical shoreline features and bank soil chemistry information, and has been made to facilitate defining the elevation at which the boundary occurs. These five areas include the following:

- **Area 1** occurs along the Crowley pier. The area under the pier includes some sediment deposits, but is mostly steeply sloped riprap next to a vertical bulkhead. The proposed removal action boundary is at the pier face. Information concerning the presence of sediments on the riprap beneath the pier,

and chemical concentrations within those sediments, may be generated during design.

- **Area 2** extends from the north edge of the Crowley pier, around the head of the slip to the edge of the easternmost outfall (i.e., the King County East Marginal Way pump station emergency overflow outfall). The proposed removal action boundary is at the toe of the bank in this area and ranges from approximately +5 to +8 feet MLLW. Bank sample BK01 (collected at approximately +10 feet MLLW) was collected northwest of the outfalls in this area and found to contain only 2.4 mg/kg OC PCBs. The bank above the boundary does not require remediation.
- **Area 3** extends from the King County outfall to the edge of the existing bulkhead on First South Properties. The proposed removal action boundary is at the toe of the bank in this region, which ranges from about +6 to +10 ft MLLW. A failed bulkhead is present in a portion of this area. Bank samples BK02 and BK03 (collected at approximately +10 ft MLLW) contained 47 mg/kg OC and 48.6 mg/kg OC PCBs, respectively. (A field replicate sample at BK02 contained 28.9 mg/kg OC PCBs,) The bank above the boundary is likely composed of fill material and will be evaluated for potential source control by Ecology.
- **Area 4** is comprised of the bulkhead on the southern half of First South Properties. The proposed removal action boundary is at the toe of the bulkhead at approximately +5 ft MLLW. Bank samples BK04 (20.2 mg/kg OC PCBs) and BK05 (26.3 mg/kg OC PCBs) represent fill material located behind the bulkhead. The bulkhead and associated fill material above the boundary will be evaluated for potential source control by Ecology.
- **Area 5** is located between the bulkhead and the northeast limits of engineered riprap that is present along the Boeing property shoreline. A chain-link fence at the top of the bank along the property line between First South Properties and Boeing coincides with the limits of the riprap. The proposed removal action boundary is at the toe of the bank in Area 5, which is located at about +5 ft MLLW. The bank in this area appears to be eroding fill material. Bank sample BK06 (collected at approximately +10 ft MLLW in this area) contained 402 mg/kg OC PCBs. The bank above the boundary is being evaluated for potential source control, investigation, and/or remedial action by Ecology.

3.4 DESIGN CONSIDERATIONS

Bank sediments/soils located above the proposed boundary may be affected by the removal action depending on the removal alternative(s) selected and engineering requirements. In the removal design, specific engineering considerations, such as slope

and structural stability will be assessed, as well as the status of Ecology's source control investigation and/or remedial actions in each embankment area. Design details will be developed to address these considerations, and the design may include elements (such as slope stabilization measures) that extend slightly outside the proposed removal boundaries.

The potential for recontamination of Slip 4 sediments caused by eroding bank soils will also be assessed in the EE/CA. Proper sequencing of any required bank remediation by Ecology and the early removal actions in the sediments will be essential to avoid recontamination of remediated areas.

3.5 STATUS OF SEDIMENTS OUTSIDE THE PROPOSED BOUNDARY

The identification of early removal actions in the LDW was an early objective of the LDWG, EPA, and Ecology. The identification of early action areas, and the subsequent removal actions within those areas, serves to more quickly reduce risks to both human health and ecological receptors than does the full RI/FS process. Sediments that are not included within a removal action boundary remain a part of the LDW RI/FS and will continue to be evaluated through that more detailed scientific process.

Sediments outside the removal boundary will be included in the residual ecological and human health risks assessments conducted as part of the RI/FS to evaluate potential risks to human health and the environment posed by the LDW site after the early actions. LDWG is also conducting a fate and transport study on the LDW. Sediments outside of the Slip 4 boundary that are found through the RI process to present unacceptable risks will be addressed in the FS.

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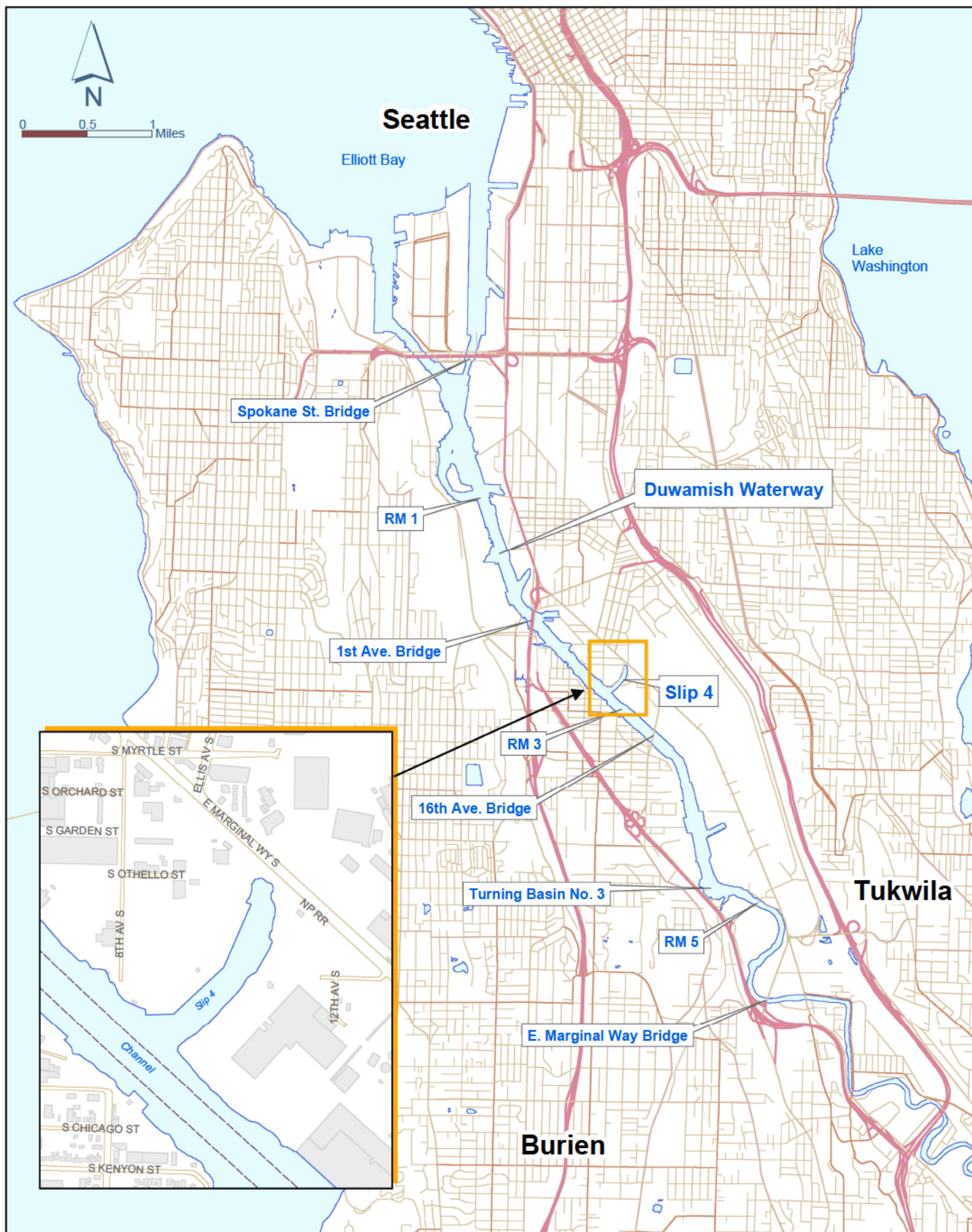
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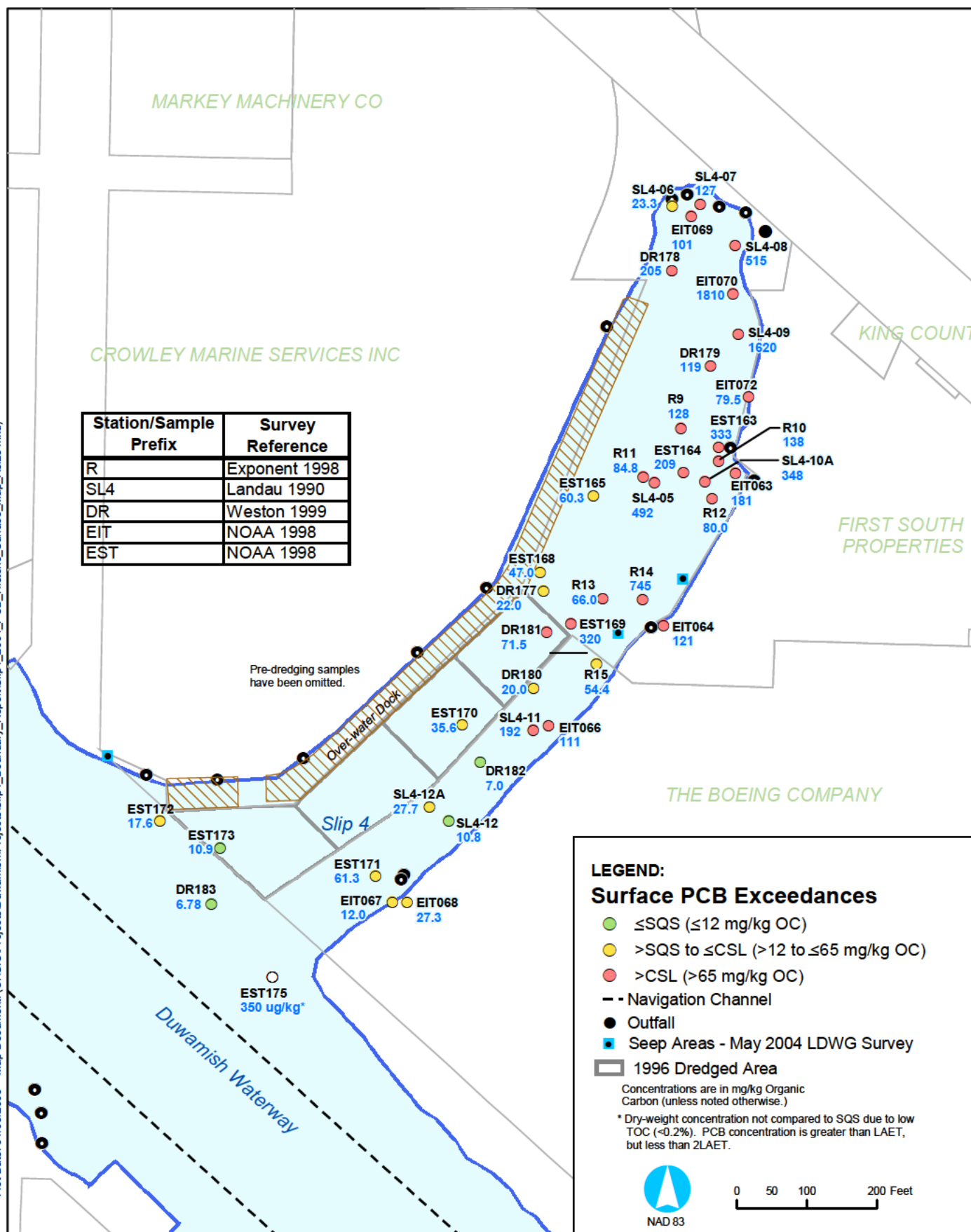
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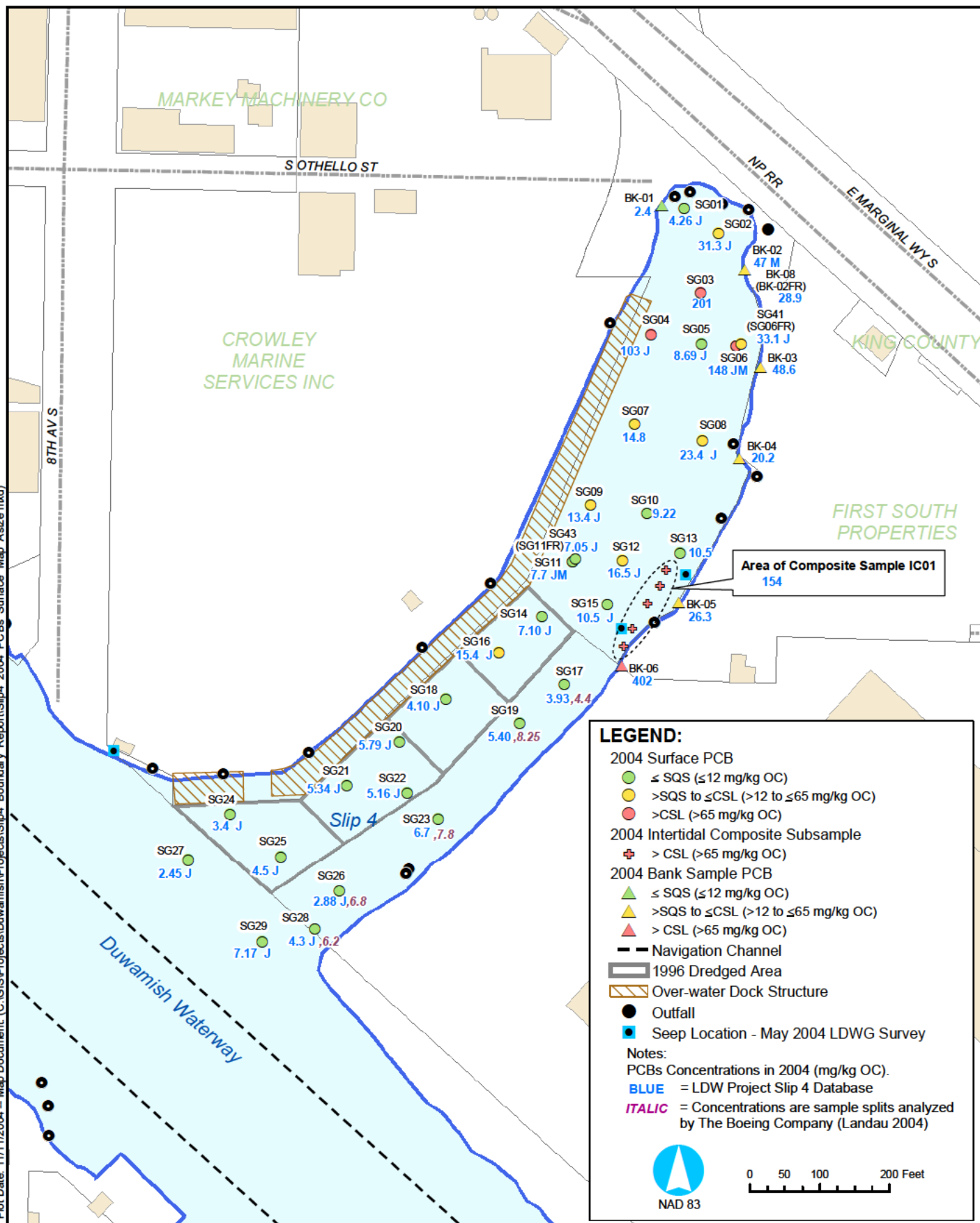
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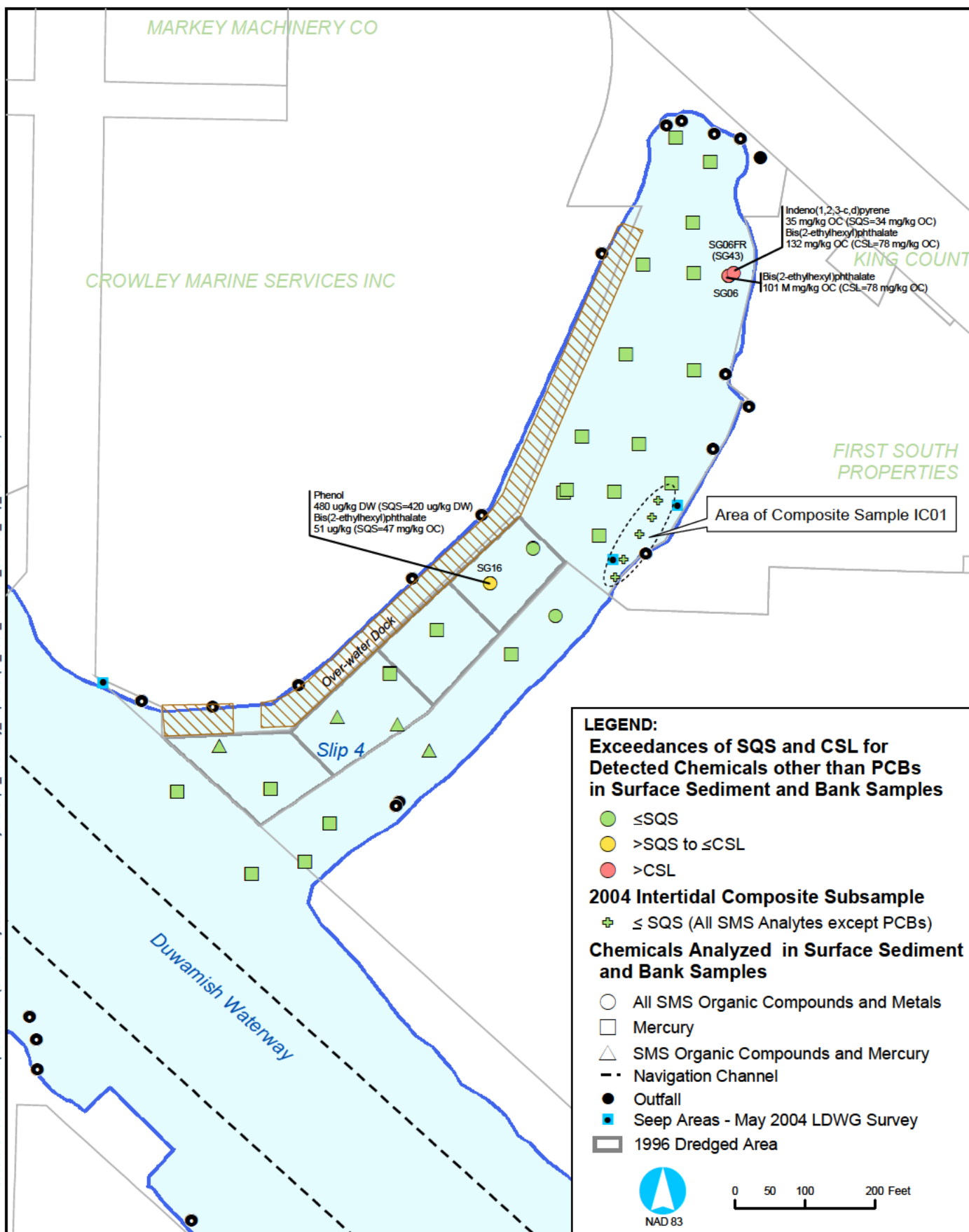
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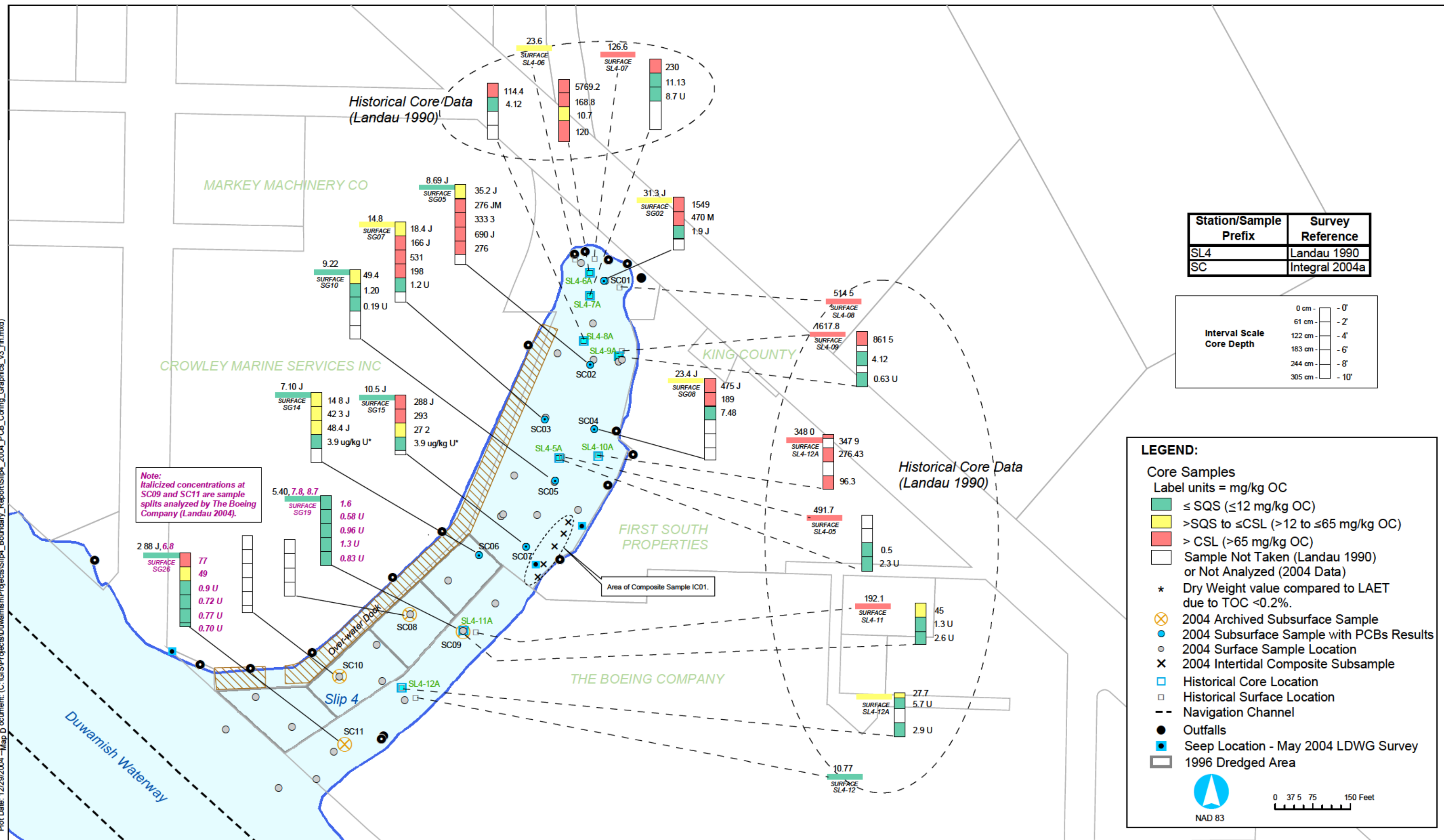


Figure 5.
Historical and 2004 PCB
Concentrations in Subsurface Sediments in Slip 4.



Table 1. Numerical Criteria for Puget Sound Marine Sediments.

	Sediment Management Standards (WAC 173-204)	
	SQS	CSL
Metals	<i>(mg/kg, dry weight)</i>	
Arsenic	57	93
Cadmium	5.1	6.7
Chromium	260	270
Copper	390	390
Lead	450	530
Mercury	0.41	0.59
Silver	6.1	6.1
Zinc	410	960
Organics	<i>(mg/kg organic carbon)</i>	
<i>LPAHs</i>	370	780
Naphthalene	99	170
Acenaphthylene	66	66
Acenaphthene	16	57
Fluorene	23	79
Phenanthrene	100	480
Anthracene	220	1,200
2-Methylnaphthalene	38	64
<i>HPAHs</i>	960	5,300
Fluoranthene	160	1,200
Pyrene	1,000	1,400
Benzo(a)anthracene	110	270
Chrysene	110	460
Benzo(a)fluoranthene	230	450
Benzo(a)pyrene	99	210
Indeno(1,2,3-c,d)pyrene	34	88
Dibenzo(a,h)anthracene	12	33
Benzo(g,h,i)perylene	31	78
<i>Chlorinated Hydrocarbons</i>		
1,4-Dichlorobenzene	3.1	9
1,2-Dichlorobenzene	2.3	2.3
1,2,4-Trichlorobenzene	0.81	1.8
Hexachlorobenzene	0.38	2.3
<i>Phthalates</i>		
Dimethylphthalate	53	53
Diethylphthalate	61	110
Di-n-butylphthalate	220	1,700
Butylbenzylphthalate	4.9	64
Bis(2-ethylhexyl)phthalate	47	78
Di-n-octylphthalate	58	4,500

Table 1. Numerical Criteria for Puget Sound Marine Sediments.

	Sediment Management Standards (WAC 173-204)	
	SQS	CSL
<i>Miscellaneous</i>		
Dibenzofuran	15	58
Hexachlorobutadiene	3.9	6.2
N-nitrosodiphenylamine	11	11
Total PCBs	12	65
<i>Ionizable Organic Compounds</i>		
	<i>(µg/kg, dry weight)</i>	
Phenol	420	1,200
2-Methylphenol	63	63
4-Methylphenol	670	670
2,4-Dimethylphenol	29	29
Pentachlorophenol	360	690
Benzyl Alcohol	57	73
Benzoic Acid	650	650

Table 2. SQS and CSL Exceedances in Surface Sediments Collected in 1990 - 1998.
(Undetected chemicals are italicized.)

Location	Depth (cm)	TOC (%)	Chemical	Concentration	SQS EF ^a	CSL EF
DR177	0-10	2.87	PCBs	22.0 mg/kg OC	1.84	--- ^b
			<i>Hexachlorobenzene</i>	0.7 U mg/kg OC	1.83	---
DR178	0-10	3.44	PCBs	205 mg/kg OC	17.06	3.15
			Bis(2-ethylhexyl)phthalate	148 mg/kg OC	3.15	1.90
			Benzo(g,h,i)perylene	61.0 J mg/kg OC	1.97	---
			Indeno(1,2,3-cd)pyrene	66.9 J mg/kg OC	1.97	---
			Dibenzo(a,h)anthracene	19.8 J mg/kg OC	1.65	---
			Butyl benzyl phthalate	7.8 mg/kg OC	1.60	---
			Mercury	0.5 mg/kg dw	1.12	---
			Benzo(a)pyrene	102 J mg/kg OC	1.03	---
			Total HPAH	982 mg/kg OC	1.02	---
			Chrysene	102 mg/kg OC	1.02	---
			Benzofluoranthenes	233 mg/kg OC	1.01	---
			<i>Hexachlorobenzene</i>	0.6 U mg/kg OC	1.53	---
DR179	0-10	2.83	PCBs	119 mg/kg OC	9.89	1.83
			Mercury	1.1 mg/kg dw	2.73	1.90
			Bis(2-ethylhexyl)phthalate	98.9 mg/kg OC	2.11	1.27
			Indeno(1,2,3-cd)pyrene	38.9 mg/kg OC	1.14	---
			<i>Hexachlorobenzene</i>	0.7 U mg/kg OC	1.86	---
DR180	0-10	2.63	PCBs	20.0 mg/kg OC	1.67	---
			<i>Hexachlorobenzene</i>	0.8 U mg/kg OC	2.00	---
DR181	0-10	2.34	PCBs	71.5 mg/kg OC	5.95	1.10
			<i>Hexachlorobenzene</i>	0.9 U mg/kg OC	2.25	---
			<i>1,2,4-Trichlorobenzene</i>	0.9 U mg/kg OC	1.06	---
DR182	0-10	4.54	<i>Hexachlorobenzene</i>	0.4 U mg/kg OC	1.16	---
DR183	0-10	1.80	<i>Hexachlorobenzene</i>	1.1 U mg/kg OC	2.92	---
			<i>1,2,4-Trichlorobenzene</i>	1.1 U mg/kg OC	1.37	---
EIT063	0-10	1.27	PCBs	181 mg/kg OC	15.09	2.79
EIT064	0-10	1.49	PCBs	121 mg/kg OC	10.07	1.86
EIT066	0-10	0.54	PCBs	111 mg/kg OC	9.26	1.71
EIT067	0-10	1.08	PCBs	12.0 mg/kg OC	1.0003	---
EIT068	0-10	0.30	PCBs	27.3 mg/kg OC	2.28	---
EIT069	0-10	3.27	PCBs	101 mg/kg OC	8.41	1.55

Table 2. SQS and CSL Exceedances in Surface Sediments Collected in 1990 - 1998.
(Undetected chemicals are italicized.)

Location	Depth (cm)	TOC (%)	Chemical	Concentration	SQS EF ^a	CSL EF
EIT070	0-10	1.39	PCBs	1810 mg/kg OC	150.42	27.77
EIT072	0-10	1.51	PCBs	79.5 mg/kg OC	6.62	1.22
EST163	0-10	2.10	PCBs	333 mg/kg OC	27.78	5.13
EST164	0-10	1.96	PCBs	209 mg/kg OC	17.43	3.22
EST165	0-10	2.32	PCBs	60.3 mg/kg OC	5.03	---
EST168	0-10	2.34	PCBs	47.0 mg/kg OC	3.92	---
EST169	0-10	2.06	PCBs	320 mg/kg OC	26.70	4.93
EST170	0-10	2.08	PCBs	35.6 mg/kg OC	2.96	---
EST171	0-10	0.31	PCBs	61.3 mg/kg OC	5.11	---
EST172	0-10	1.70	PCBs	17.6 mg/kg OC	1.47	---
EST175	0-10	0.13	PCBs	350 mg/kg dw	2.69 ^c	---
R9	0-10	2.30	PCBs	128 mg/kg OC	10.69	1.97
			Bis(2-ethylhexyl)phthalate	65.2 mg/kg OC	1.39	---
			<i>1,2,4-Trichlorobenzene</i>	<i>0.8 U mg/kg OC</i>	<i>1.02</i>	---
R10	0-10	2.30	PCBs	138 mg/kg OC	11.52	2.13
			Bis(2-ethylhexyl)phthalate	100 mg/kg OC	2.13	1.28
			Indeno(1,2,3-cd)pyrene	38.3 mg/kg OC	1.13	---
			Dibenzo(a,h)anthracene	12.2 J mg/kg OC	1.01	---
			<i>1,2,4-Trichlorobenzene</i>	<i>0.8 U mg/kg OC</i>	<i>1.02</i>	---
R11	0-10	2.10	PCBs	84.8 mg/kg OC	7.06	1.30
			Bis(2-ethylhexyl)phthalate	66.7 mg/kg OC	1.42	---
			<i>1,2,4-Trichlorobenzene</i>	<i>0.9 U mg/kg OC</i>	<i>1.12</i>	---
R12	0-10	2.00	PCBs	80.0 mg/kg OC	6.67	1.23
			<i>1,2,4-Trichlorobenzene</i>	<i>1.0 U mg/kg OC</i>	<i>1.17</i>	---
R13	0-10	2.00	PCBs	66.0 mg/kg OC	5.50	1.02
			<i>1,2,4-Trichlorobenzene</i>	<i>1.0 UJ mg/kg OC</i>	<i>1.17</i>	---
R14	0-10	2.20	PCBs	745 mg/kg OC	62.12	11.47
			Hexachlorobenzene	4.4 UJ mg/kg OC	11.60	1.92
			<i>1,2,4-Trichlorobenzene</i>	<i>0.9 U mg/kg OC</i>	<i>1.07</i>	---
R15	0-10	2.50	PCBs	54.4 mg/kg OC	4.53	---

Table 2. SQS and CSL Exceedances in Surface Sediments Collected in 1990 - 1998.
(Undetected chemicals are italicized.)

Location	Depth (cm)	TOC (%)	Chemical	Concentration	SQS EF ^a	CSL EF
SL4-05	0-10	2.40	PCBs	492 mg/kg OC	40.97	7.56
			Bis(2-ethylhexyl)phthalate	150 mg/kg OC	3.19	1.92
			<i>Hexachlorobenzene</i>	1.4 U mg/kg OC	3.73	---
			<i>Benzyl alcohol</i>	170 U ug/kg dw	2.98	2.33
			<i>2,4-Dimethylphenol</i>	68.0 U ug/kg dw	2.34	2.34
			<i>1,2,4-Trichlorobenzene</i>	1.4 U mg/kg OC	1.75	---
SL4-06	0-10	4.30	Bis(2-ethylhexyl)phthalate	256 K mg/kg OC	5.44	3.28
			Butyl benzyl phthalate	11.6 mg/kg OC	2.37	---
			PCBs	23.3 mg/kg OC	1.94	---
			Phenanthrene	186 mg/kg OC	1.86	---
			N-Nitrosodiphenylamine	18.1 mg/kg OC	1.65	1.65
			Zinc	536 mg/kg dw	1.31	---
			Dibenzo(a,h)anthracene	15.6 mg/kg OC	1.30	---
			Lead	507 mg/kg dw	1.13	---
			Di-n-octyl phthalate	62.8 mg/kg OC	1.08	---
			<i>Benzyl alcohol</i>	160 U ug/kg dw	2.81	2.19
			<i>2,4-Dimethylphenol</i>	66.0 U ug/kg dw	2.28	2.28
			<i>Hexachlorobenzene</i>	0.8 U mg/kg OC	2.02	---
SL4-07	0-10	3.50	PCBs	127 mg/kg OC	10.55	1.95
			Bis(2-ethylhexyl)phthalate	246 mg/kg OC	5.23	3.15
			Acenaphthene	37.1 mg/kg OC	2.32	---
			Fluoranthene	371 mg/kg OC	2.32	---
			Lead	721 mg/kg dw	1.60	1.36
			Zinc	491 mg/kg dw	1.20	---
			Mercury	0.5 mg/kg dw	1.15	---
			Dibenzo(a,h)anthracene	13.4 mg/kg OC	1.12	---
			Indeno(1,2,3-cd)pyrene	37.1 mg/kg OC	1.09	---
			Chrysene	109 mg/kg OC	1.09	---
			Total HPAH	976 mg/kg OC	1.02	---
			Benzo(a)anthracene	111 mg/kg OC	1.01	---
			<i>Benzyl alcohol</i>	430 U ug/kg dw	7.54	5.89
			<i>Hexachlorobenzene</i>	2.5 U mg/kg OC	6.54	1.08
			<i>2,4-Dimethylphenol</i>	170 U ug/kg dw	5.86	5.86
			<i>1,2,4-Trichlorobenzene</i>	2.5 U mg/kg OC	3.07	1.38
			<i>2-Methylphenol</i>	87.0 U ug/kg dw	1.38	1.38
			<i>Benzoic acid</i>	870 U ug/kg dw	1.34	1.34
			<i>Hexachlorobutadiene</i>	4.9 U mg/kg OC	1.25	---
			<i>Pentachlorophenol</i>	430 U ug/kg dw	1.19	---
			<i>1,2-Dichlorobenzene</i>	2.5 U mg/kg OC	1.08	1.08

Table 2. SQS and CSL Exceedances in Surface Sediments Collected in 1990 - 1998.
(Undetected chemicals are italicized.)

Location	Depth (cm)	TOC (%)	Chemical	Concentration	SQS EF ^a	CSL EF
SL4-08	0-10	2.00	PCBs	515 mg/kg OC	42.88	7.92
			Bis(2-ethylhexyl)phthalate	185 mg/kg OC	3.94	2.37
			Fluoranthene	365 mg/kg OC	2.28	---
			Dibenzo(a,h)anthracene	21.5 mg/kg OC	1.79	---
			Indeno(1,2,3-cd)pyrene	60.0 mg/kg OC	1.76	---
			Chrysene	150 mg/kg OC	1.50	---
			Phenanthrene	150 mg/kg OC	1.50	---
			Cadmium	7.5 mg/kg dw	1.47	1.12
			Benzo(a)anthracene	125 mg/kg OC	1.14	---
			Mercury	0.5 mg/kg dw	1.12	---
			Total HPAH	1066 mg/kg OC	1.11	---
			Benzofluoranthenes	255 mg/kg OC	1.11	---
			Zinc	411 mg/kg dw	1.002	---
			<i>Hexachlorobenzene</i>	3.6 U mg/kg OC	9.34	1.54
			<i>Benzyl alcohol</i>	350 U ug/kg dw	6.14	4.79
			<i>2,4-Dimethylphenol</i>	140 U ug/kg dw	4.83	4.83
			<i>1,2,4-Trichlorobenzene</i>	3.6 U mg/kg OC	4.38	1.97
			<i>Hexachlorobutadiene</i>	7.0 U mg/kg OC	1.79	1.13
			<i>1,2-Dichlorobenzene</i>	3.6 U mg/kg OC	1.54	1.54
			<i>1,4-Dichlorobenzene</i>	3.6 U mg/kg OC	1.15	---
			<i>2-Methylphenol</i>	71.0 U ug/kg dw	1.13	1.13
			<i>Benzoic acid</i>	710 U ug/kg dw	1.09	1.09
SL4-09	0-10	2.10	PCBs	1619 mg/kg OC	134.92	24.91
			Bis(2-ethylhexyl)phthalate	52.4 mg/kg OC	1.11	---
			<i>Hexachlorobenzene</i>	2.9 U mg/kg OC	7.52	1.24
			<i>Benzyl alcohol</i>	300 U ug/kg dw	5.26	4.11
			<i>2,4-Dimethylphenol</i>	120 U ug/kg dw	4.14	4.14
			<i>1,2,4-Trichlorobenzene</i>	2.9 U mg/kg OC	3.53	1.59
			<i>Hexachlorobutadiene</i>	5.7 U mg/kg OC	1.47	---
			<i>1,2-Dichlorobenzene</i>	2.9 U mg/kg OC	1.24	1.24
SL4-10	0-10	0.68	Bis(2-ethylhexyl)phthalate	324 mg/kg OC	6.88	4.15
			Butyl benzyl phthalate	6.9 J mg/kg OC	1.41	---
			Di-n-octyl phthalate	76.5 mg/kg OC	1.32	---
			Indeno(1,2,3-cd)pyrene	44.1 mg/kg OC	1.30	---
			Fluoranthene	206 mg/kg OC	1.29	---
			Dibenzo(a,h)anthracene	14.7 mg/kg OC	1.23	---
			Chrysene	110 mg/kg OC	1.10	---
			<i>Hexachlorobenzene</i>	9.6 U mg/kg OC	25.15	4.16
			<i>1,2,4-Trichlorobenzene</i>	9.6 U mg/kg OC	11.80	5.31
			<i>Benzyl alcohol</i>	330 U ug/kg dw	5.79	4.52
			<i>Hexachlorobutadiene</i>	19.1 U mg/kg OC	4.90	3.08
			<i>2,4-Dimethylphenol</i>	130 U ug/kg dw	4.48	4.48
			<i>1,2-Dichlorobenzene</i>	9.6 U mg/kg OC	4.16	4.16
			<i>1,4-Dichlorobenzene</i>	9.6 U mg/kg OC	3.08	1.06
			<i>2-Methylphenol</i>	65.0 U ug/kg dw	1.03	1.03

Table 2. SQS and CSL Exceedances in Surface Sediments Collected in 1990 - 1998.
(Undetected chemicals are italicized.)

Location	Depth (cm)	TOC (%)	Chemical	Concentration	SQS EF ^a	CSL EF
SL4-10A	0-15	1.67	PCBs	348 mg/kg OC	29.00	5.35
			Bis(2-ethylhexyl)phthalate	198 mg/kg OC	4.21	2.54
			<i>Hexachlorobenzene</i>	3.9 U mg/kg OC	10.26	1.70
			<i>Benzyl alcohol</i>	320 U ug/kg dw	5.61	4.38
			<i>1,2,4-Trichlorobenzene</i>	3.9 U mg/kg OC	4.81	2.17
			<i>2,4-Dimethylphenol</i>	130 U ug/kg dw	4.48	4.48
			<i>Hexachlorobutadiene</i>	7.8 U mg/kg OC	2.00	1.26
			<i>1,2-Dichlorobenzene</i>	3.9 U mg/kg OC	1.70	1.70
			<i>1,4-Dichlorobenzene</i>	3.9 U mg/kg OC	1.26	---
			<i>2-Methylphenol</i>	65.0 U ug/kg dw	1.03	1.03
SL4-11	0-10	0.38	PCBs	192 mg/kg OC	16.01	2.96
			Bis(2-ethylhexyl)phthalate	65.8 mg/kg OC	1.40	---
			<i>Hexachlorobenzene</i>	14.5 U mg/kg OC	38.09	6.29
			<i>1,2,4-Trichlorobenzene</i>	14.5 U mg/kg OC	17.87	8.04
			<i>Hexachlorobutadiene</i>	28.9 U mg/kg OC	7.42	4.67
			<i>1,2-Dichlorobenzene</i>	14.5 U mg/kg OC	6.29	6.29
			<i>Benzyl alcohol</i>	280 U ug/kg dw	4.91	3.84
			<i>1,4-Dichlorobenzene</i>	14.5 U mg/kg OC	4.67	1.61
			<i>2,4-Dimethylphenol</i>	110 U ug/kg dw	3.79	3.79
			<i>Butyl benzyl phthalate</i>	14.5 U mg/kg OC	2.95	---
			<i>N-Nitrosodiphenylamine</i>	14.5 U mg/kg OC	1.32	1.32
			<i>Dibenzo(a,h)anthracene</i>	14.5 U mg/kg OC	1.21	---
SL4-12	0-10	0.52	Bis(2-ethylhexyl)phthalate	190 mg/kg OC	4.05	2.44
			Fluoranthene	231 mg/kg OC	1.44	---
			Chrysene	110 mg/kg OC	1.10	---
			<i>Hexachlorobenzene</i>	11.7 U mg/kg OC	30.87	5.10
			<i>1,2,4-Trichlorobenzene</i>	11.7 U mg/kg OC	14.48	6.52
			<i>Hexachlorobutadiene</i>	23.1 U mg/kg OC	5.92	3.72
			<i>Benzyl alcohol</i>	310 U ug/kg dw	5.44	4.25
			<i>1,2-Dichlorobenzene</i>	11.7 U mg/kg OC	5.10	5.10
			<i>2,4-Dimethylphenol</i>	120 U ug/kg dw	4.14	4.14
			<i>1,4-Dichlorobenzene</i>	11.7 U mg/kg OC	3.78	1.30
			<i>Butyl benzyl phthalate</i>	11.7 U mg/kg OC	2.39	---
			<i>N-Nitrosodiphenylamine</i>	11.7 U mg/kg OC	1.07	1.07
SL4-12A	0-15	0.78	PCBs	27.7 mg/kg OC	2.31	---

Notes:

U = Undetected.

J = Estimated.

K = Reported concentration is less than the detection limit.

^a SQS EF(exceedance factor) = concentration in sample/SQS. CSL EF = concentration in sample/CSL.

^b Concentration does not exceed CSL or 2LAET.

^c Compared to LAET (130 ug/kg dw) and 2LAET (1,000 ug/kg dw) because TOC is <0.2%.

Table 3. SQS and CSL Exceedances in Surface Sediment and Bank Samples Collected in 2004.
(Undetected chemicals are italicized.) Note: These data are also shown in Figure 8 of the *Cruise and Data Report*
(Integral 2004a).

	Depth						
Location	(cm)	TOC (%)	Chemical	Concentration		SQS EF ^a	CSL EF
Surface Sediment							
SG02	0-10	5.18	PCBs	31.3 J	mg/kg OC	2.61	--- ^b
SG03	0-10	2.54	PCBs	201	mg/kg OC	16.73	3.09
SG04	0-10	4.78	PCBs	103 J	mg/kg OC	8.61	1.59
SG06	0-10	3.18	PCBs	148 JM	mg/kg OC	12.40	2.29
			Bis(2-ethylhexyl)phtalate	101 M	ug/kg dw	2.17	1.31
			Hexachlorobenzene	3.77 UM	mg/kg OC	9.93	1.64
			1,2,4-Trichlorobenzene	3.77 UM	mg/kg OC	4.66	2.10
			2,4-Dimethylphenol	120 UM	ug/kg dw	4.14	4.14
			Benzyl alcohol	120 UM	ug/kg dw	2.11	1.64
			2-Methylphenol	120 UM	ug/kg dw	1.90	1.90
			Benzoic acid	1200 UM	ug/kg dw	1.85	1.85
			1,2-Dichlorobenzene	3.77 UM	mg/kg OC	1.64	1.64
			Pentachlorophenol	580 UM	ug/kg dw	1.61	---
			1,4-Dichlorobenzene	3.77 UM	mg/kg OC	1.22	---
SG06FR	0-10	3.41	Bis(2-ethylhexyl)phtalate	132	ug/kg dw	2.81	1.69
			PCBs	33.1 J	mg/kg OC	2.76	---
			Indeno(1,2,3-cd)pyrene	35.2	mg/kg OC	1.04	---
			Hexachlorobenzene	3.52 U	mg/kg OC	9.26	1.53
			1,2,4-Trichlorobenzene	3.52 U	mg/kg OC	4.34	1.96
			2,4-Dimethylphenol	120 U	ug/kg dw	4.14	4.14
			Benzyl alcohol	120 U	ug/kg dw	2.11	1.64
			2-Methylphenol	120 U	ug/kg dw	1.90	1.90
			Benzoic acid	1200 U	ug/kg dw	1.85	1.85
			Pentachlorophenol	590 U	ug/kg dw	1.64	---
			1,2-Dichlorobenzene	3.52 U	mg/kg OC	1.53	1.53
			1,4-Dichlorobenzene	3.52 U	mg/kg OC	1.14	---
SG07	0-10	3.18	PCBs	14.8	mg/kg OC	1.23	---
SG08	0-10	3.04	PCBs	23.4 J	mg/kg OC	1.95	---
SG09	0-10	3.61	PCBs	13.4 J	mg/kg OC	1.11	---
SG12	0-10	3.2	PCBs	16.5 J	mg/kg OC	1.38	---
SG14	0-10	2.79	Hexachlorobenzene	0.72 U	mg/kg OC	1.89	---
SG16	0-10	0.817	PCBs	15.4 J	mg/kg OC	1.29	---
			Phenol	480	ug/kg dw	1.14	---
			Bis(2-ethylhexyl)phthalate	51	mg/kg OC	1.09	---
			Hexachlorobenzene	2.33 U	mg/kg OC	6.12	1.01
			1,2,4-Trichlorobenzene	2.33 U	mg/kg OC	2.87	1.29

Table 3. SQS and CSL Exceedances in Surface Sediment and Bank Samples Collected in 2004.
(Undetected chemicals are italicized.) Note: These data are also shown in Figure 8 of the *Cruise and Data Report*
(Integral 2004a).

Location	Depth (cm)	TOC (%)	Chemical	Concentration		SQS EF ^a	CSL EF
			1,2-Dichlorobenzene	2.33 U	mg/kg OC	1.01	1.01
SG17	0-10	2.94	Hexachlorobenzene	0.68 U	mg/kg OC	1.79	---
SG21	0-10	2.96	Hexachlorobenzene	0.68 U	mg/kg OC	1.78	---
SG22	0-10	2.81	Hexachlorobenzene	0.71 U	mg/kg OC	1.87	---
SG23	0-10	0.716	Hexachlorobenzene	2.65 U	mg/kg OC	6.98	1.15
			1,2,4-Trichlorobenzene	2.65 U	mg/kg OC	3.28	1.47
			1,2-Dichlorobenzene	2.65 U	mg/kg OC	1.15	1.15
SG24	0-10	2.88	Hexachlorobenzene	0.69 U	mg/kg OC	1.83	---
IC01	0-10	1.07	PCBs	154	mg/kg OC	12.83	2.37
			Hexachlorobenzene	11.2 U	mg/kg OC	29.51	4.88
			1,2,4-Trichlorobenzene	11.2 U	mg/kg OC	13.85	6.23
			1,2-Dichlorobenzene	11.2 U	mg/kg OC	4.88	4.88
			2,4-Dimethylphenol	120 U	ug/kg dw	4.14	4.14
			1,4-Dichlorobenzene	11.2 U	mg/kg OC	3.62	1.25
			Hexachlorobutadiene	11.2 U	mg/kg OC	2.88	1.81
			Butylbenzyl phthalate	11.2 U	mg/kg OC	2.29	---
			Benzyl alcohol	120 U	ug/kg dw	2.11	1.64
			2-Methylphenol	120 U	ug/kg dw	1.90	1.90
			Benzoic acid	1200 U	ug/kg dw	1.85	1.85
			Pentachlorophenol	580 U	ug/kg dw	1.61	---
			N-Nitrosodiphenylamine	11.2 U	mg/kg OC	1.02	1.02
Bank							
BK02	0-10	8.23	PCBs	47 M	mg/kg OC	3.91	---
BK02FR	0-10	9.39	PCBs	28.9	mg/kg OC	2.40	---
BK03	0-10	1.75	PCBs	48.6	mg/kg OC	4.05	---
BK04	0-10	3.92	PCBs	20.2	mg/kg OC	1.68	---
BK05	0-10	4.95	PCBs	26.3	mg/kg OC	2.19	---
BK06	0-10	1.94	PCBs	402	mg/kg OC	33.51	6.18

Notes:

U = Undetected.

J = Estimated.

M = Mean of field duplicate results.

^a SQS EF(exceedance factor) = concentration in sample/SQS. CSL EF = concentration in sample/CSL.

^bConcentration does not exceed CSL.

Table 4. SQS and CSL Exceedances in Subsurface Sediment Samples Collected in 2004.

(Undetected chemicals are italicized.) Note: These data are also shown in Figure 9 of the *Cruise and Data Report* (Integral 2004a).

	Depth						
Location	(ft)	TOC (%)	Chemical	Concentration		SQS EF ^a	CSL EF
SC01	0-2	2.26	PCBs	1549	mg/kg OC	129	23.8
			Mercury	10.3	mg/kg dw	25.1	17.5
			Mercury - reanalysis	0.99	mg/kg dw	2.41	1.68
	2-4	0.30	PCBs	470 M	mg/kg OC	39.1	7.22
			Hexachlorobenzene	6 U	mg/kg OC	16	2.64
			1,2,4-Trichlorobenzene	6 U	mg/kg OC	7.51	3.38
			1,2-Dichlorobenzene	6 U	mg/kg OC	2.64	2.64
			1,4-Dichlorobenzene	6 U	mg/kg OC	1.96	--- ^b
			Hexachlorobutadiene	6 U	mg/kg OC	1.56	---
			Butylbenzyl phthalate	6 U	mg/kg OC	1.24	---
	4-6	0.20	Hexachlorobenzene	9 U	mg/kg OC	24.8	4.09
			1,2,4-Trichlorobenzene	9 U	mg/kg OC	11.6	5.23
			1,2-Dichlorobenzene	9 U	mg/kg OC	4.09	4.09
			1,4-Dichlorobenzene	9 U	mg/kg OC	3.03	1.05
			Hexachlorobutadiene	9 U	mg/kg OC	2.41	1.52
			Butylbenzyl phthalate	9 U	mg/kg OC	1.92	---
SC02	0-2	3.41	PCBs	35.2 J	mg/kg OC	2.93	---
	2-4	3.01	PCBs	276 MJ	mg/kg OC	23	4.24
	4-6	3.27	PCBs	333	mg/kg OC	27.8	5.13
			Mercury	0.51	mg/kg dw	1.24	---
	6-8	2.52	PCBs	690 J	mg/kg OC	57.5	10.62
			Mercury	0.82	mg/kg dw	2	1.39
			Silver	6.4	mg/kg dw	1.05	1.05
			Hexachlorobenzene	1 U	mg/kg OC	3.34	---
			1,2,4-Trichlorobenzene	1 U	mg/kg OC	1.57	---
			2,4-Dimethylphenol	32 U	mg/kg OC	1.1	1.1
	8-10	1.96	PCBs	276	mg/kg OC	23	4.24
			Hexachlorobenzene	1 U	mg/kg OC	3.89	---
			1,2,4-Trichlorobenzene	1 U	mg/kg OC	1.83	---
			2,4-Dimethylphenol	29 U	mg/kg OC	1	1
SC03	0-2	3.04	PCBs	18.4 J	mg/kg OC	1.53	---
	2-4	2.90	PCBs	166 J	mg/kg OC	13.9	2.56
	4-6	2.77	PCBs	531	mg/kg OC	44.2	8.16
			Mercury	0.48	mg/kg OC	1.17	---
	6-8	1.18	PCBs	198	mg/kg OC	16.5	3.05
			Hexachlorobenzene	2 U	mg/kg OC	4.68	---
			1,2,4-Trichlorobenzene	2 U	mg/kg OC	2.2	---
	8-10	0.33	Hexachlorobenzene	6 U	mg/kg OC	15.4	2.54
			1,2,4-Trichlorobenzene	6 U	mg/kg OC	7.22	3.25
			1,2-Dichlorobenzene	6 U	mg/kg OC	2.54	2.54
			1,4-Dichlorobenzene	6 U	mg/kg OC	1.89	---
			Hexachlorobutadiene	6 U	mg/kg OC	1.5	---
Butylbenzyl phthalate			6 U	mg/kg OC	1.19	---	

Table 4. SQS and CSL Exceedances in Subsurface Sediment Samples Collected in 2004.

(Undetected chemicals are italicized.) Note: These data are also shown in Figure 9 of the *Cruise and Data Report* (Integral 2004a).

Location	Depth (ft)	TOC (%)	Chemical	Concentration	SQS EF ^a	CSL EF
SC04	0-2	3.01	PCBs	475 J mg/kg OC	39.6	7.31
	2-4	5.13	PCBs	189 mg/kg OC	15.8	2.91
	4-6	4.01	Mercury	0.71 mg/kg dw	1.73	---
			<i>Hexachlorobenzene</i>	1 U mg/kg OC	3.48	---
			<i>2,4-Dimethylphenol</i>	53 U mg/kg OC	1.83	1.83
			<i>1,2,4-Trichlorobenzene</i>	1 U mg/kg OC	1.63	---
	6-8	not analyzed	Mercury	0.49 mg/kg dw	1.2	---
SC05	0-2	2.65	PCBs	49.4 mg/kg OC	4.12	---
	2-4	2.22	<i>Hexachlorobenzene</i>	1 U mg/kg OC	2.13	---
			<i>1,2,4-Trichlorobenzene</i>	1 U mg/kg OC	1	---
SC06	0-2	2.39	PCBs	14.8 J mg/kg OC	1.23	---
	2-4	2.34	PCBs	42.3 J mg/kg OC	3.53	---
	4-6	1.59	PCBs	48.4 J mg/kg OC	4.04	---
SC07	0-2	2.39	PCBs	288 J mg/kg OC	24.1	4.44
	2-4	2.49	PCBs	293 mg/kg OC	24.4	4.51
			Mercury	0.47 mg/kg dw	1.15	---
	4-6	1.37	PCBs	27.2 mg/kg OC	2.26	---
			<i>Hexachlorobenzene</i>	3 U mg/kg OC	7.68	1.27
			<i>1,2,4-Trichlorobenzene</i>	3 U mg/kg OC	3.6	1.62
			<i>2,4-Dimethylphenol</i>	40 U mg/kg OC	1.38	1.38
			<i>1,2-Dichlorobenzene</i>	3 U mg/kg OC	1.27	1.27
	6-8	0.16	<i>Hexachlorobutadiene</i>	14 U ug/kg dw	1.27 ^c	---
SC11 ^d	0-2	2.30	PCBs	77 mg/kg OC	6.41	1.18
	2-4	1.22	PCBs	49 mg/kg OC	4.1	---

Notes:

U = Undetected.

J = Estimated.

^a SQS EF(exceedance factor) = concentration in sample/SQS. CSL EF = concentration in sample/CSL.

^bConcentration does not exceed CSL or 2LAET.

^cCompared to LAET (11 ug/kg dw) because TOC is <0.2%.

^dSample analyzed for PCBs by The Boeing Company.



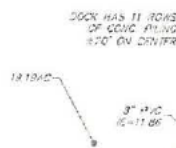
LOWER DUWAMISH WATERWAY SLIP 4 EARLY ACTION AREA












REVISED DRAFT TECHNICAL MEMORANDUM ON PROPOSED BOUNDARY OF THE REMOVAL ACTION

APPENDIX A

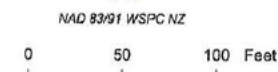
Slip 4 Topographic and Hydrographic Contour Map with
Proposed Removal Boundary

January 14, 2005



	INDICATES POWER POLE
	INDICATES SANITARY MANHOLE
	INDICATES LUMINARE
	INDICATES IRRIGATION CONTROL VALVE
	INDICATES GUY WIRE
	INDICATES SPOT ELEVATION
	INDICATES 5 FOOT CONTOUR INTERVAL
	INDICATES 1 FOOT CONTOUR INTERVAL
	PROPOSED REMOVAL BOUNDARY
	APPROXIMATE PROPERTY LINE
	INDICATES EDGE OF WATER AT 7: 43AM - 8: 54AM ON 09-22-04 (1.5 - 3.5 FT MLLW)

1. HORIZONTAL DATUM: WASHINGTON STATE PLANE COORDINATE SYSTEM, NORTH ZONE (NAD-83/91), U.S. FEET.
2. CONTOURS ARE SHOWN IN FEET AT AN INTERVAL OF 1 FOOT AND INDICATE ELEVATIONS IN REFERENCE TO MEAN LOWER LOW WATER (MLLW). THE BENCH MARK USED IS "DEA 2005" MLLW ELEVATION 16.17'.
3. HORIZONTAL POSITIONS FOR NAVIGATION AND DATA COLLECTION WERE DETERMINED BY USING A TRIMBLE 4700 G.P.S. SYSTEM OPERATING IN DIFFERENTIAL MODE, USING THE G.P.S. CONTINUOUSLY OPERATING REFERENCE STATION (CORS).
4. BATHYMETRIC DATA WAS COLLECTED USING KNUDSEN 320M ECHOSOUNDER WITH A 6 DEGREE SINGLE BEAM TRANSDUCER, OPERATING AT 200 KHZ.
5. SURVEY DATA WAS COLLECTED PARALLEL WITH THE DOCK USING A TEN FOOT LINE SPACING. THE SURVEY DATA COLLECTED ALONG EACH SURVEY LINE WAS THINNED USING A "SHOAL BIAS" METHOD TO AN APPROXIMATE HORIZONTAL SPACING OF 2 FEET.
6. THERE MAY BE BOTTOM FEATURES THAT ARE NOT SHOWN ON THIS MAP DUE TO THE LINE SPACING INTERVAL. THIS SURVEY DOES NOT INCLUDE BATHYMETRIC DATA BETWEEN THE ADJACENT SURVEY LINES.
7. THIS BATHYMETRIC SURVEY IS REPRESENTATIVE OF THE CONDITION OF THE BOTTOM AT THE TIME OF THE SURVEY, BASED ON THE LINE SPACING INTERVAL AND THINNING METHOD USED. THE CONDITION OF THE BOTTOM MAY CHANGE AT ANY TIME AFTER THE DATE OF THIS SURVEY.
8. BATHYMETRIC DATA WAS COLLECTED IN ACCORDANCE WITH THE U.S. ARMY CORPS OF ENGINEERS HYDROGRAPHIC MANUAL EM-1112-02-1003 (JANUARY 2002).
9. DATA COLLECTED: OCTOBER 5, 2004
10. TOPOGRAPHIC & HYDROGRAPHIC BASE INFORMATION PROVIDED BY MINISTER-GLAESER SURVEYING INC, 2200 E. EVERGREEN BLVD., VANCOUVER, WA 98661; MGS JOB#: 04-368; MGS DRAWING NAME: 043581.DWG.



Lower Duwamish Waterway Slip 4 Early Action Area

Appendix B Summary of City of Seattle and King County Source Control Activities in the Slip 4 Drainage Basin

1 INTRODUCTION

The source control strategy for the Lower Duwamish Waterway (LDW) is to minimize the potential for chemicals in sediments to exceed the Washington State Sediment Management Standards (SMS) and LDW cleanup goals by identifying and managing pollutant sources. Washington Department of Ecology (Ecology) is working in concert with the members of the LDW Source Control Work Group (City of Seattle, King County, the Port of Seattle, the City of Tukwila, and the U.S Environmental Protection Agency) to achieve this goal. Controlling sources within the early action areas in the LDW is a top priority since these areas will be cleaned up first. Information in this appendix was provided by Seattle Public Utilities (SPU) (Schmoyer 2006a,b, pers. comm.; King County and SPU 2004, 2005a,b).

This appendix includes the latest available information as of this writing. King County and SPU will continue to update this information in progress reports to the agencies every 6 months.

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2 CITY OF SEATTLE AND KING COUNTY SOURCE CONTROL ACTIVITIES

The City of Seattle owns and operates the municipal separated storm drain system that collects stormwater runoff from upland areas and discharges to Slip 4 and the small sanitary/combined sewer system that collects municipal and industrial wastewater within the City service area. King County owns and operates the larger interceptor system that conveys wastewater to the treatment plant at West Point. The City and King County each own and operate sewer pump stations that in an emergency would discharge overflow to Slip 4.

City and County source control activities focus on reducing the amount of chemicals discharged to publicly owned storm drains and sanitary/combined sewers through business inspections and source identification/tracing work. Because there are no combined sewer overflows (CSOs) into Slip 4 and pump station emergency overflows occur infrequently, source control activities have focused on stormwater discharges. The City and County provide progress reports to the agencies every 6 months. Detailed information is available in the June 2004, January 2005, and June 2005 reports (King County and SPU 2004, 2005a,b).

2.1 BUSINESS INSPECTIONS

King County Industrial Waste and SPU are leading the joint King County-Seattle business inspection program in the LDW. Inspections are conducted under existing code authorities. Since June 2004, a total of 55 businesses (all of the airport tenants and waterfront facilities, except Boeing-owned or lease facilities) have been inspected in the Slip 4 drainage basin (46 full inspections and 9 screening inspections). Boeing facilities have not been inspected because inspectors were not granted access to these facilities.

Of the 46 sites receiving full inspections, 35 required some type of corrective action. Most of the problems found in the Slip 4 drainage were related to spill prevention and cleanup (e.g., lack of proper spill prevention and cleanup plans or inadequate employee training in spill prevention and cleanup practices). Other common problems included lack of adequate spill control materials onsite and need for cleaning of onsite drainage facilities. Inspectors requested a total of 103 corrective actions in the Slip 4 basin. Corrective actions requested are summarized in Table B-1.

As of December 2005, 88 percent of the sites that were requested to make corrective actions have completed the required changes (King County and SPU 2005b). Inspectors are working with the three remaining facilities to obtain compliance.

2.2 SOURCE TRACING AND IDENTIFICATION

SPU and King County are conducting source tracing and identification sampling activities to support the source control efforts. Source tracing is designed to identify sources by strategically collecting samples at key locations within the drainage system. Source identification sampling focuses on product testing to determine whether specific products contain chemicals that are a concern for waterway sediment.

The following types of source samples have been collected within the Slip 4 drainage basin:

- In-line sediment traps installed in the storm drain system (10 stations)
- Catch basin and other sediment samples from upland sites (9 samples)
- In-line sediment collected from maintenance holes on the storm drain trunk lines (5 samples with duplicate analyses)
- Sediment samples from the Georgetown flume (11 samples).

Source sediment sample results are reported in Tables B-2 through B-4. The results are compared to the SMS to provide a rough indication of overall quality. The SMS establishes the sediment quality standards (SQS), which identify surface sediments that have no adverse effects on biological resources, and the cleanup screening level (CSL), which is the "minor adverse effects" level used as an upper regulatory threshold for making decisions about cleanup. It should be emphasized that the SMS do not apply to storm drain sediments. It is important to note that any comparison of this kind is most likely conservative given that sediments discharged from storm drains are highly dispersed in the receiving environment and mixed with the natural sedimentation taking place in the waterway.

2.2.1 Storm Drain Sediment Traps

In March 2005, SPU installed sediment traps at the following 10 stations in the publicly owned storm drains that discharge to Slip 4 (Figure B-1):

- SL4-T1 (MH422): 60-inch King County Airport SD #3/PS44 EOF at the downstream end of the north and central laterals.
- SL4-T2 and SL4-T2A (MH356 and MH482): 60-inch King County Airport SD #3/PS44 EOF, south lateral (downstream and upstream of the Boeing lease property).
- SL4-T3 and SL4-T3A (MH364 and MH19C): 60-inch King County Airport SD #3/PS44 EOF, central lateral#1 (downstream and upstream of the Boeing lease property).

- SL4-T4 and SL4-T4A (MH221A and MH229A): 60-inch King County Airport SD #3/PS44 EOF, central lateral #2 (downstream and upstream of the Boeing lease property).
- SL4-T5 and SL4-T5A (MH363 and MH178): King County Airport SD #3/PS44 EOF, north lateral (downstream and upstream of the Boeing lease property).
- SL4-T6: 72-inch I-5 SD at the intersection of S. Hardy Street and Airport Way S.

Traps are installed for a 4- to 6-month period to passively collect samples of suspended sediment present in the stormwater runoff. In August 2005, SPU and Boeing removed and redeployed the traps for the winter wet season.

Results from the first round of samples are provided in Tables B-2a and B-2b. Chemicals that exceeded SMS include mercury, zinc, BEHP, and PCBs. Mercury concentrations (0.1–1.12 mg/kg DW) exceeded the CSL in three traps (SL4-T1, SL4-T5, and SL4-T5A) and zinc (220–553 mg/kg DW) exceeded the SQS in 3 traps (SL4-T4A, SL4-T5, and SL4-T6). TOC was not analyzed in all samples because of low sample volumes and so comparisons with SMS for organic compounds could only be performed on three of the sediment trap samples (SL4-T1, SL4-T4A, and SL4-T6). BEHP (49–189 mg/kg OC) exceeded the SMS in all three samples (two SQS exceedances and one CSL exceedance).

PCBs were detected in all 10 traps at concentrations ranging from 0.04 to 24 mg/kg DW and exceeded the MTCA Method A cleanup level for residential soil of 1 mg/kg DW in five traps. Due to limited sample volume, TOC analysis was performed in only three samples, and therefore only these samples could be compared to the SMS. Two of the three samples (SL4-T1 and SL4-T6, 233 and 246 mg/kg OC PCBs, respectively) exceeded the CSL for PCBs.

2.2.2 Inline Sediment Samples

In addition to the sediment trap samples, SPU collected inline sediment samples at four of the stations where traps were deployed and one additional maintenance hole at the downstream end of the flume (MH100). Duplicate samples were collected at each site and split with Boeing. Inline samples are grab samples collected from sediment that has deposited in the storm drain line, typically at maintenance holes or other areas where sediment accumulates. Inline sediment data are provided in Tables B-3a and B-3b. Sampling locations are shown on Figure B-1.

Chemicals exceeding SMS included mercury, zinc, acenaphthene, fluorene, phenanthrene, benzo [b+k]fluoranthene, benzo[g,h,i]perylene, fluoranthene, , indeno[1,2,3-c,d]pyrene, BEHP, and PCBs. Mercury (0.48/0.7 mg/kg DW) exceeded the CSL in split samples at MH363, while zinc (411 and 572 mg/kg DW) exceeded the SQS at MH100 and MH221A and the CSL (699/1,130 mg/kg DW) in split samples at MH229A.

Concentrations of PAH compounds exceeded the SQS in only one of the two split samples at MH229A and MH221A

BEHP concentrations in the Slip 4 inline sediment samples (180–2,200 µg/kg DW) were relatively low compared to other source sediment samples collected in the Lower Duwamish Waterway (<20–26,000 µg/kg DW). However, samples from three of the five locations (MH221A, MH363, and MH229A) exceeded the SQS.

PCBs were detected at four of the five inline sample locations (0.31–31 mg/kg DW), exceeding the SQS at one location (MH100) and the CSL at three locations (MH221A, MH363, and MH229A). MH363 contained the highest concentration of PCBs (31 mg/kg DW or 2,793 mg/kg OC), consisting of Aroclor 1254, although the detection limits for other Arcolors in this sample were relatively high (0.47–3.8 mg/kg DW or 42–342 mg/kg OC). Aroclors 1254 (0.15–3.7 mg/kg DW, 3–96 mg/kg OC) and 1260 (0.16–1.9 mg/kg DW, 4–53 mg/kg OC) were present in the other three locations where PCBs were detected.

2.2.3 Catch Basins and Other Source Sediment Samples

SPU has collected sediment samples from eight catch basins and one upland site drainage ditch in the Slip 4 drainage basin (Figure B-1):

- **CB37:** Located on the Crowley property and drains directly to Slip 4
- **CB44:** Located in a parking area on S. Myrtle Street that drains to the Georgetown flume
- **CB45 and CB46:** Located at the King County maintenance facility on the north end of the airport. CB45 drains to the I-5 SD, and CB46 drains to the King County Airport SD #3/PS44 EOF
- **CB48:** Located on the west side of the Georgetown Steam Plant and drains to the Georgetown flume
- **CB79 and CB80:** Oil/water separator and catch basin, respectively. Both are located on Emerald Services property at head of Slip 4. CB79 drains directly to Slip 4, and CB80 drains to the combined sewer on E. Marginal Way South.
- **RCB49:** Located on S. Webster Street on the east side of Slip 4 and drains to the combined sewer on E. Marginal Way South.
- **S1:** Drainage ditch on Emerald Services property and drains to Slip 4. Results for this soil sample are discussed in Section 2.3.2.2 of the main text.

The catch basin sampling results are summarized in Tables B-4a and B-4b. Chemicals exceeding SMS include copper, lead, zinc, fluorene, phenanthrene, benzo(a)anthracene, benzo(a)pyrene, benzo(b+k)fluoranthenes, benzo(g,h,i)perylene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno[1,2,3-c,d]pyrene, BEHP, butylbenzylphthalate, dimethylphthalate, di-n-octylphthalate, and PCBs.

Zinc exceeded the CSL in the two catch basins at the King County maintenance facility (3,420–3,530 mg/kg) and the Crowley catch basin (1,220 mg/kg DW). Zinc also exceeded the SQS in the samples collected from the S. Myrtle Street drain (524 mg/kg DW), the steam plant catch basin (657 mg/kg DW), and the oil/water separator (CB79) on the Emerald Services site (758 mg/kg DW). The highest concentrations were found in the two King County Airport catch basins, which are on a drain line that receives runoff from a metal finishing facility. Copper (5,660–6,320 mg/kg DW) also exceeded the CSL in these two catch basins, and lead (481 mg/kg DW) exceeded the SQS in one catch basin (CB45). The airport has since cleaned these catch basins and is planning to install outlet traps on appropriate catch basins (King County and SPU 2005b).

PAH concentrations were also elevated in the two catch basins at the King County maintenance facility, with exceedances of the SQS or CSL for several HPAH compounds and exceedances of SQS for two LPAH compounds. CB48 at the Georgetown Steam Plant also contained elevated concentrations of PAH (one LPAH and five HPAH compounds exceeded the SQS).

The highest BEHP concentrations (exceeding CSL) were found in samples collected on the Emerald Services site (5,500–120,000 µg/kg DW, 177–1,869 mg/kg OC) and the two catch basins at the King County maintenance facility (8,800–30,000 µg/kg DW, 90–288 mg/kg DW). CB79, also on the Emerald Services site, exceeded the SQS for di-n-octylphthalate (62 mg/kg OC). In addition, CB80 exceeded the CSL for butylbenzylphthalate (1,800 µg/kg DW, 67 mg/kg OC) and dimethylphthalate (1,900 µg/kg DW, 71 mg/kg OC), as well as the SQS for di-n-octylphthalate (1,800 µg/kg DW, 67 mg/kg OC).

Concentrations of PCBs (<0.1–0.68 mg/kg DW) in all nine samples were below the MTCA Method A limit (1 mg/kg DW). However, CB48 at the Georgetown Steam Plant (0.25 mg/kg DW, 15.9 mg/kg OC) exceeded the SQS.

2.2.4 Georgetown Flume

SPU also investigated the Georgetown flume in 2005 (HEC 2005). As part of the investigation, the flume was surveyed and inspected and illicit connections identified. In addition, sediment samples were collected from the flume at five evenly spaced transects and adjacent to five pipe connections (see Figure B-1). Duplicate samples (T2 and T5) were obtained at the S. Myrtle Street sampling location. Sample results are presented in Tables B-3a and B-3b.

Lead (590J mg/kg DW), mercury (1.7 mg/kg DW), and zinc (1,130 mg/kg DW) exceeded the CSL at the steam plant (uppermost end of the flume). Lead (501 mg/kg DW) and zinc (766 mg/kg DW) concentrations exceeded the SQS and mercury (1 mg/kg DW) exceeded the CSL at the downstream end of the tunnel section (below the steam plant). TPH-oil was elevated at the steam plant (9,700 mg/kg DW) and in the drainage ditch that runs along the north side of S. Myrtle Street (3,000 mg/kg DW). In addition, TPH-diesel (2,300 mg/kg DW) was elevated at the steam plant.

BEHP concentrations were generally low in the flume samples (120–3,800 µg/kg DW, 2–75 mg/kg OC), with only 3 of the 11 samples exceeding the SQS.

PCB concentrations exceeded the SMS at multiple locations along the flume, ranging from 5 to 1,746 mg/kg OC (0.038–92 mg/kg DW). Of the 10 flume sediment samples, two samples exceeded the CSL for PCBs (T3 and P3), and four samples exceeded the SQS for PCBs (T4, T6, P1, and P2). In addition, the sample collected from the ditch entering the flume at S. Myrtle Street (P5) also exceeded the SQS for PCBs (1.5 mg/kg DW, 22 mg/kg OC). PCB concentrations (0.78–92 mg/kg DW) were generally higher at the upper end of the flume (above S. Willow Street) compared to the downstream end (0.065–0.4 mg/kg DW). The highest concentration (92 mg/kg DW/1,746 mg/kg OC) was observed adjacent to the 15-inch storm drain (P3) that enters just downstream of the tunnel section. This storm drain is now plugged. The P3 sample contained only Aroclor 1254. Other samples generally contained a mixture of Aroclor 1254 and 1260, with some samples also containing Aroclor 1248.

Inspectors found six unplugged pipes entering the flume during the field investigation. Four pipes, ranging in size from 3 to 8 inches, enter along the west side of the flume and appear to be private outfalls from adjacent properties. One 4-inch PVC pipe is an illicit connection from a motel's laundry system. The laundry cannot be replumbed to the motel's existing septic system because it is not capable of handling the additional flow from the laundry. There are no sanitary sewer lines near the property. Consequently, the motel has since stopped using this system and now sends all laundry offsite for washing. Another pipe (8-inch concrete) is a storm drain that serves the properties along the south side of S. Myrtle Street. The source of the remaining four pipes is unknown.

Two pipes (6–8 inches) enter the flume from the east side. One of these pipes enters along the piped section located between about S. Willow Street and the tunnel, and the other enters in the concrete-lined section about 100 feet upstream of S. Willow Street. The source of these two pipes is unknown.

Seattle City Light and SPU are currently investigating options for removing the PCB-contaminated material, as well as long-term operation of the flume. Options being considered include permanently closing the flume and rerouting drainage to other nearby storm drain systems or installing a new piped storm drain along the flume

alignment and backfilling the flume. The City intends to complete this work in 2007-2008.

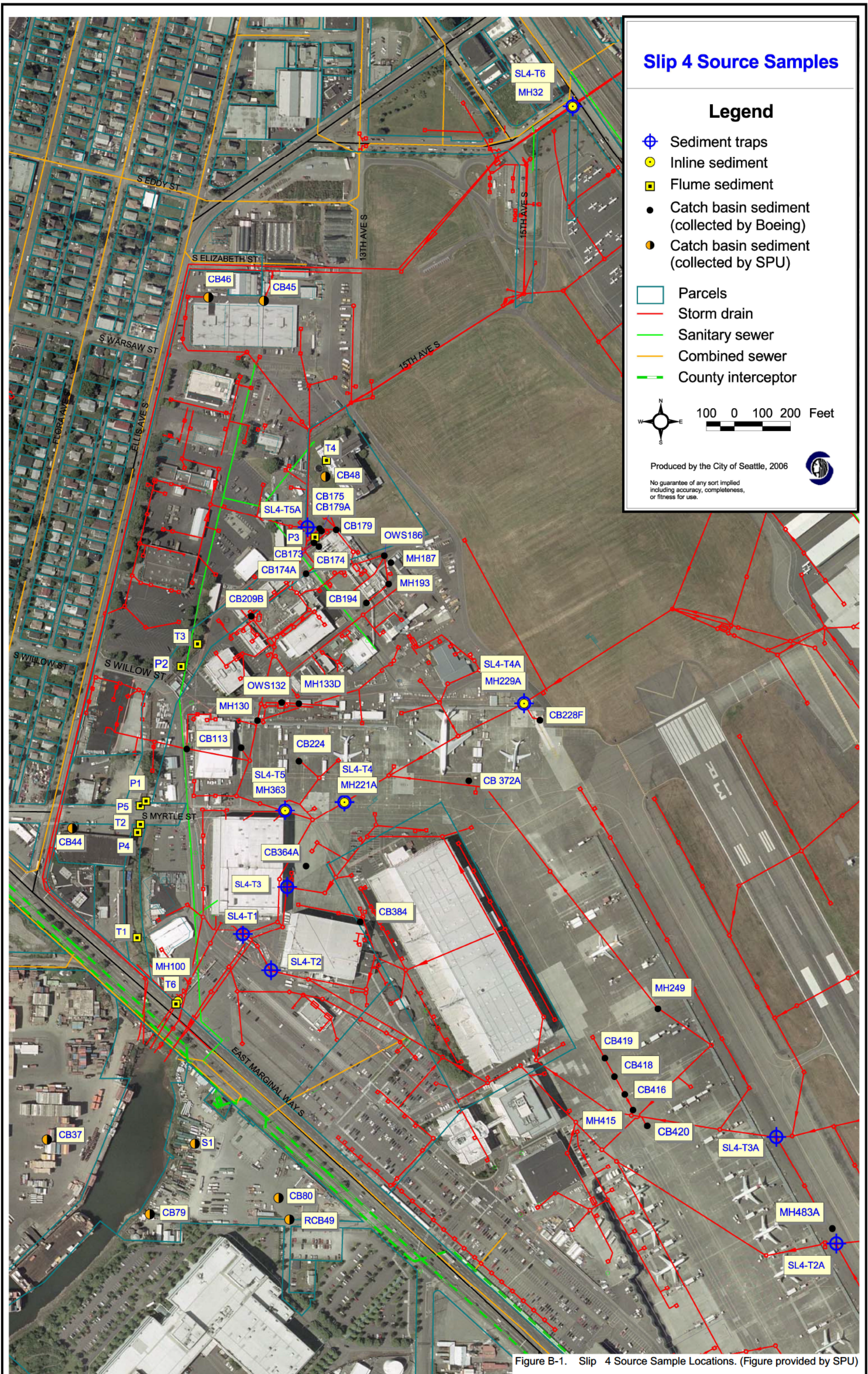


Table B-1. Corrective Actions Requested of Businesses in Slip 4 Basin
(June 2004—December 2005).

Corrective Action	Percentage of Sites^a
Facility lacks proper spill prevention/cleanup plan/procedures	24
Inadequate employee training on spill prevention/cleanup practices	21
Inadequate spill cleanup materials available onsite	15
Drainage facility needs cleaning	13
Improper storage of hazardous products and waste materials	6
Improper hazardous waste disposal	6
Improper outdoor storage of nonhazardous materials/products	5

^a Reported as percentage of total sites inspected. Note that not all sites had corrective actions and some sites had multiple corrective actions; therefore, percentages do not total 100%.

Table B-2a Slip 4 Drainage Basin Sediment Trap Results (mg/kg DW).

Seattle Public Utilities ID King County/Boeing MH#	SL4-T1 MH422 KC Airport SD, north + central #1 lat	SL4-T2A MH482 KC Airport SD, south lat, d/s runway	SL4-T2 MW356 KC Airport SD, south lat, d/s Boeing Field	SL4-T3A MH19C KC Airport SD, central lat #2, d/s runway	SL4-T3 MH364 KC Airport SD, central lat #2, d/s Boeing Field	SL4-T4A MH229A KC Airport SD, central lat #1, d/s runway	SL4-T4 MH221A KC Airport SD, central lat #1, d/s Boeing Field	SL4-T5A MH178 KC Airport SD, north lat, d/s Steamplant	SL4-T5 MH363 KC Airport SD, north lat, d/s Boeing Field	SL4-T6 NA I-5 SD at Airport Way S
	Round 1	Round1	Round 1	Round 1	Round 1	Round 1	Round 1	Round 1	Round 1	Round 1
Date deployed		03/10/05	03/07/05	03/10/05	03/07/05	03/08/05	03/08/05	03/08/05	03/07/05	
Date removed	08/11/05	08/11/05	08/11/05	08/11/05	08/11/05	08/11/05	08/11/05	08/11/05	08/11/05	08/11/05
Sample collected by	Boeing	SPU	Boeing	SPU	Boeing	Boeing	Boeing	Boeing	Boeing	SPU
TOC (percent)	4.29	NA	NA	NA	NA	5.35	NA	NA	NA	3.17
Metals (mg/kg DW)										
As	11	NA	NA	NA	NA	16	NA	14	21	11
Cu	83.6	NA	NA	NA	NA	94.3	NA	113	148	84.5
Pb	140	NA	NA	NA	NA	144	NA	962	109	110
Hg	1.10	NA	NA	NA	NA	0.19	NA	0.86	1.12	0.10
Zn	368	NA	NA	NA	NA	460	NA	220	553	422
LPAH (ug/kg DW)										
Acenaphthene	210	NA	NA	NA	NA	160 U	1,300	110 U	130 U	79 U
Acenaphthylene	100 U	NA	NA	NA	NA	160 U	210 U	110 U	130 U	79 U
Anthracene	360	NA	NA	NA	NA	180	1,500	150	210	98
Fluorene	190	NA	NA	NA	NA	160 U	1,000	110 U	130 U	79 U
Naphthalene	100 U	NA	NA	NA	NA	160 U	670	110 U	130 U	79 U
Phenanthrene	2,800	NA	NA	NA	NA	1,700	8,600	1,300	1,600	570
HPAH (ug/kg DW)										
Benzo(a)anthracene	1,400	NA	NA	NA	NA	860	3,000	840	940	270
Benzo(a)pyrene	1,700	NA	NA	NA	NA	1,400	3,400	1,100	1,200	250
Benzo(b)fluoranthene	2,400	NA	NA	NA	NA	2,100	4,600	1,600	1,700	380
Benzo(k)fluoranthene	1,300	NA	NA	NA	NA	1,300	2,600	800	970	220
Benzo(g,h,i)perylene	720	NA	NA	NA	NA	710	1,600	450	600	79 U
Chrysene	1,900	NA	NA	NA	NA	1,700	4,100	1,200	1,400	370
Dibenzo(a,h)anthracene	260	NA	NA	NA	NA	160 U	730	110 U	130 U	79 U
Fluoranthene	4,100	NA	NA	NA	NA	3,100	8,900	2,400	2,900	880
Indeno(1,2,3-c,d)pyrene	810	NA	NA	NA	NA	780	1,900	520	680	84
Pyrene	3,000	NA	NA	NA	NA	2,100	6,800	1,700	2,000	630
Phthalates (ug/kg DW)										
Bis(2-ethylhexyl)phthalate	2,400	NA	NA	NA	NA	2,600	6,000	1,800	2,700	6,000
Butylbenzylphthalate	120	NA	NA	NA	NA	160 U	210 U	110 U	140	420
Diethylphthalate	100 U	NA	NA	NA	NA	160 U	210 U	110 U	130 U	79 U
Dimethylphthalate	100 U	NA	NA	NA	NA	160 U	210 U	110 U	130 U	79 U
Di-n-butylphthalate	130	NA	NA	NA	NA	350	260	150	130 U	460
Di-n-octylphthalate	440	NA	NA	NA	NA	4,300	3,700	220	1,200	430
PCBs (ug/kg DW)										
Aroclor 1016	29 U	48 U	21 U	34 U	20 U	9.8 U	9.8 U	9.6 U	49 U	1,800 U
Aroclor 1242	29 U	48 U	21 U	34 U	20 U	9.8 U	9.8 U	9.6 U	49 U	1,800 U
Aroclor 1248	29 U	48 U	21 U	34 U	20 U	9.8 U	9.8 U	9.6 U	49 U	1,800 U
Aroclor 1254	10,000	67	500 P	38 JP	1,400	290 P	1,900 P	72	24,000	1,800 U
Aroclor 1260	1,200 U	110	340	34 U	380 U	160	850	34	2,400 U	7,800
Aroclor 1221	29 U	48 U	21 U	34 U	20 U	9.8 U	9.8 U	9.6 U	49 U	1,800 U
Aroclor 1232	29 U	48 U	21 U	34 U	20 U	9.8 U	9.8 U	9.6 U	49 U	1,800 U
Total PCBs	10,000	177	840 P	38 JP	1,400	450 P	2,750 P	106	24,000	7,800
TPH (mg/kg)										
Diesel	230	NA	NA	NA	NA	100	NA	160	390	310
Motor Oil	970	NA	NA	NA	NA	410	NA	570	1,400	800

Detected values shown in bold type.

NA = not analyzed

U = Chemical not detected at reported concentration

J = Chemical concentration is reported as estimate.

P = Chemical detected on both chromatographic columns, but values differ by >40% RPD with no obvious interference.

Exceeds SQS (0.41 mg/kg mercury, 410 mg/kg zinc) or MTCA Method A soil cleanup level for unrestricted use (1 mg/kg PCBs)

Exceeds CSL (0.59 mg/kg mercury) or MTCA Method A soil cleanup level for industrial use (10 mg/kg PCBs)

Table B-2b: Slip 4 Drainage Basin Sediment Trap Results Compared to Sediment Management Standards.

Seattle Public Utilities ID King County/Boeing MH#	SQS	CSL	SL4-T1 MH422 KC Airport SD, north + central #1 lat	SL4-T4A MH229A KC Airport SD, central lat #1, d/s runway	Slip4-T6 NA I-5 SD at Airport Way S
			Round 1	Round1	Round 1
Date deployed				03/08/05	
Date removed			08/11/05	08/11/05	08/11/05
Sampled by			Boeing	Boeing	SPU
TOC (percent)			4.29	5.35	3.17
Metals (mg/kg DW)					
As	57	93	11	16	11
Cu	390	390	83.6	94.3	84.5
Pb	450	530	140	144	110
Hg	0.41	0.59	1.10	0.19	0.1
Zn	410	960	368	460	422
LPAH (mg/kg OC)					
Acenaphthene	16	57	5	3 U	2.5 U
Acenaphthylene	66	66	2 U	3 U	2.5 U
Anthracene	220	1,200	8	3	3.1
Fluorene	23	79	4	3 U	2.5 U
Naphthalene	99	170	2 U	3 U	2.5 U
Phenanthrene	100	480	65	32	18
HPAH (mg/kg OC)					
Benzo(a)anthracene	110	270	33	16	8.5
Benzo(a)pyrene	99	210	40	26	7.9
Benzo(b+k)fluoranthene	230	450	86	64	12.0
Benzo(g,h,i)perylene	31	78	17	13	6.9
Chrysene	110	460	44	32	11.7
Dibenzo(a,h)anthracene	12	33	6	3 U	2.5 U
Fluoranthene	160	1,200	96	58	27.8
Indeno(1,2,3-c,d)pyrene	34	88	19	15	2.6
Pyrene	1,000	1,400	70	39	19.9
Phthalates (mg/kg OC)					
Bis(2-ethylhexyl)phthalate	47	78	56	49	189
Butylbenzylphthalate	4.9	64	3	3 U	13
Diethylphthalate	61	110	2 U	3 U	2 U
Dimethylphthalate	53	53	2 U	3 U	2 U
Di-n-butylphthalate	220	1,700	3	7	15
Di-n-octylphthalate	58	4,500	10	80	14
PCBs (mg/kg OC)					
Aroclor 1016			1 U	0.2 U	57 U
Aroclor 1242			1 U	0.2 U	57 U
Aroclor 1248			1 U	0.2 U	57 U
Aroclor 1254			233	5.4 P	57 U
Aroclor 1260			28 U	3.0	246
Aroclor 1221			1 U	0.2 U	57 U
Aroclor 1232			1 U	0.2 U	57 U
Total PCBs	12	65	233	8.4 P	246
TPH (mg/kg)					
Diesel		2000 ^a		100	310
Motor Oil		2000 ^a		410	800

Detected values shown in bold type.

^aMTCA Method A soil cleanup level for unrestricted and industrial use.

U = Chemical not detected at reported concentration

P = Chemical detected on both chromatographic columns, but values differ by >40% RPD with no obvious interference.

Exceeds SQS

Exceeds CSL or MTCA Method A soil cleanup level.

Table B-3a: Slip 4 Drainage Basin inline sediment sample results (dry weight).

Slip 4 Storm Drains									
	MH100 North+ central lat #2	MH100 North+ central lat #2	MH221A Central lat #1, d/s Boeing Field	MH221A Central lat #1, d/s Boeing Field	MH363 North lat, d/s Steampl	MH363 North lat, d/s Steampl	MH229A Central lat #1, d/s runway	MH229A Central lat #1, d/s runway	MH32 I-5 SD at Airport Wy
Date	2/16/05 S	2/16/05 B	2/16/05 S	2/16/05 B	2/16/05 S	2/16/05 B	2/16/05 S	2/16/05 B	8/11/05 S
TOC (percent)	6.11	6.6	1 09	1	1.11	0.76	4.34	3.88	0.739
Metals (mg/kg DW)									
As	20	20	40	12	9	8	30	30	10 U
Cu	88.9	102	126	38.5	64.1	45.1	69.7	85.5	61.2
Pb	134	142	94	50	51	110	120	155	207
Hg	0.2	0.2	0.09	0.09	0.48	0.7	0.07	0.07	0.05 U
Zn	377	411	572	332	208	272	699	1,130	186
LPAH (ug/kg DW)									
Acenaphthene	100 U	59 U	180 U	58 U	59 U	59 U	800	930	20 U
Acenaphthylene	100 U	59 U	180 U	58 U	59 U	59 U	86	220 U	20 U
Anthracene	100 U	140	180 U	71	65	59 U	770	1,200	20 U
Fluorene	100 U	59 U	180 U	73	59 U	59 U	810	1,100	20 U
Naphthalene	100 U	59 U	59 U	58 U	59 U	59 U	76	220 U	22 U
Phenanthrene	500	250	440	300	400	260	6,100	8,900	22
HPAH (ug/kg DW)									
Benzo(a)anthracene	320	380	330	280	340	280	1,900	3,000	20 U
Benzo(a)pyrene	290	480	470	400	330	300	2,000	3,400	26
Benzo(b)fluoranthene	500	760	740	710	520	450	3,300	5,400	34
Benzo(g,h,i)perylene	210	200	310	230	170	170	840	1,300	20 U
Benzo(k)fluoranthene	280	460	370	400	280	310	2,000	3,600	20 U
Chrysene	570	620	600	490	500	400	2,600	4,200	31
Dibenzo(a,h)anthracene	100 U	59 U	180 U	58 U	59 U	59 U	370	220 U	20 U
Fluoranthene	980	880	1,100	920	840	750	6,700	11,000	44
Indeno(1,2,3-c,d)pyrene	240	180	380	260	190	180	980	1,500	20 U
Pyrene	750	810	800	870	630	660	4,900	7,600	50
Phthalates (ug/kg DW)									
Bis(2-ethylhexyl)phthalate	1,500	2,000	800	760	430	500	1,200	2,200	180
Butylbenzylphthalate	140	86	180 U	58 U	59 U	59 U	62	220 U	20 U
Diethylphthalate	100 U	59 U	180 U	58 U	59 U	59 U	61 U	220 U	20 U
Dimethylphthalate	100 U	59 U	180 U	58 U	59 U	59 U	61 U	220 U	20 U
Di-n-butylphthalate	100 U	59 U	180 U	58 U	59 U	59 U	110	220 U	20 U
Di-n-octylphthalate	100 U	71	180 U	120	59	69	130	240	20 U
PCBs (ug/kg DW)									
Aroclor 1016	220 U	95 U	120 U	120 U	1,200 Y	950 U	19 U	140 U	19 U
Aroclor 1242	220 U	95 U	120 U	120 U	940 Y	950 U	19 U	140 U	19 U
Aroclor 1248	220 U	95 U	120 U	120 U	2,400 Y	1,900 U	19 U	140 U	19 U
Aroclor 1254	1,000	1,600	590	960	31,000	7,000	150	3,700	19 U
Aroclor 1260	820 P	380 P	410	530	3,800 Y	950 U	160 P	1,900	19 U
Aroclor 1221	220 U	95 U	120 U	120 U	470 U	480 U	19 U	140 U	19 U
Aroclor 1232	220 U	95 U	120 U	120 U	1,400 Y	1,400 U	19 U	140 U	19 U
Total PCBs	1,820 P	1,980 P	1,000	1,490	31,000	7,000	310 P	5,600	19 U
TPH (mg/kg)									
Diesel	88	40	120	120	120	47	110	200	120 U
Motor Oil	380	190	270	210	680	190	380	1,000	290

Detected values shown in bold type.

U = Chemical not detected at reported concentration

Y = Chemical not detected at the reported concentration. Reporting limit raised due to chromatographic interference.

P = Chemical detected on both chromatographic columns, but values differ by >40% RPD with no obvious interference.

J = Chemical concentration is reported as estimate.

Exceeds SQS (450 mg/kg lead, 0.41 mg/kg mercury, 410 mg/kg zinc) or MTCA Method A soil cleanup level for unrestricted use (1 mg/kg PCBs)

Exceeds CSL (530 mg/kg lead, 0.59 mg/kg mercury, 960 mg/kg zinc) or MTCA Method A soil cleanup level for industrial use (10 mg/kg PCBs)

Table B-3a: Slip 4 Drainage Basin inline sediment sample results (dry weight).

Georgetown Flume Samples											
	T1 Flume 15' u/s of box culvert	T2 Flume at S Myrtle St	T5 ¹ Flume at S Myrtle St	T3 Flume upstream of S Willow St	T4 Head of flume	T6 MH100 u/s of E Marginal Wy S	P1 Flume off of 8" plugged pipe	P2 Flume off of 8" pipe near S Willow St	P3 Flume off of 15" plugged pipe	P4 Flume off of 8" pipe at S Myrtle St	P5 Ditch at S Myrtle St
Date	3/24/05 S	3/24/05 S	3/24/05 S	3/25/05 S	3/24/05 S	3/25/05 S	3/25/05 S	3/25/05 S	3/25/05 S	3/24/05 S	3/24/05 S
TOC (percent)	3.92	1.43	1.17	2.25	8.71	2.68	0.711	2.47	5.27	0.773	6.86
Metals (mg/kg DW)											
As	11	7 U	7 U	7 U	40	7 U	7 U	13	20	6 U	10 U
Cu	63.2	18.5	20.2	54.6	314 J	79.6	18	56.6	133	12.8	95.1
Pb	99	14	15	263	590 J	61	16	69	501	10	73
Hg	0.1	0.05 U	0.05 U	0.41	1.7	0.08	0.05 U	0.18	1	0.06 U	0.08
Zn	218	53.8	61.3	180	1,130	240	60.8	238	766	52.7	195
LPAH (ug/kg DW)											
Acenaphthene	270	20 U	24	380	660	67	20 U	58 U	120 U	19 U	1,600 U
Acenaphthylene	150	20 U	21	230	2,700	34 J	28	92	120 U	19	1,600 U
Anthracene	640	53	91	590	2,500	220	97	270	130	69	1,600 U
Fluorene	240	20 U	20 U	530	1,900	66	20 U	42 J	120 U	19 U	1,600 U
Naphthalene	310	20 U	20 U	97	2,400	59 U	20 U	58 U	120 U	19 U	1,600 U
Phenanthrene	4,500	44	67	6,200	11,000	740	96	250	510	140	1,600 U
HPAH (ug/kg DW)											
Benzo(a)anthracene	1,300	100	150	1,400	7,900	520	150	370	370	73	1,600 U
Benzo(a)pyrene	1,300	240	310	490	8,600	560	130	290	450	83	1,600 U
Benzo(b)fluoranthene	1,600	240	350	850	11,000	640	140	520	640	100	1,600 U
Benzo(g,h,i)perylene	570	92	130	200	2,500	210	52	120	190	33	1,600 U
Benzo(k)fluoranthene	1,600	270	290	1,000	9,400	790	230	540	500	140	1,600 U
Chrysene	2,300	160	210	1,500	8,400	750	230	650	540	160	810 J
Dibenzo(a,h)anthracene	230	34	41	45 J	1,000	54 J	20 U	33 J	120 U	19 U	1,600 U
Fluoranthene	6,300	200	260	6,100	18,000	1,600	530	1,200	1,100	490	1,000
Indeno(1,2,3-c,d)pyrene	660	91	120	220	3,000	210	57	120	210	32	1,600 U
Pyrene	3,200	130	180	3,300	14,000	1,200	300	850	960	230	1,200
Phthalates (ug/kg DW)											
Bis(2-ethylhexyl)phthalate	2,000	140	140	580	210	2,000	120	560	2,100	140	3,800
Butylbenzylphthalate	110	20 U	20 U	59 U	200 U	100	20 U	58 U	160	19 U	1,600 U
Diethylphthalate	60 U	20 U	20 U	59 U	200 U	59 U	20 U	58 U	120 U	19 U	1,600 U
Dimethylphthalate	60 U	20 U	20 U	59 U	200 U	59 U	20 U	58 U	120 U	19 U	1,600 U
Di-n-butylphthalate	87	20 U	20 U	60	200 U	59 U	24	69	140	19 U	1,600 U
Di-n-octylphthalate	60 U	20 U	20 U	59 U	200 U	64	20 U	230	140	19 U	1,600 U
PCBs (ug/kg DW)											
Aroclor 1016	59 U	7.8 U	4.0 U	2,800 U	240 U	40 U	12 U	79 U	26,000 U	3.9 U	240 U
Aroclor 1242	59 U	7.8 U	4.0 U	2,800 U	240 U	40 U	12 U	79 U	26,000 U	3.9 U	240 U
Aroclor 1248	59 U	12	12 J	2,800 U	1,500 J	79 U	28	210	26,000 U	6.3	240 U
Aroclor 1254	190	26 J	29 J	3,900	1,700	240	56 J	450	92,000	14 J	470 U
Aroclor 1260	140	28	24	2,800 U	540	160	36	120	26,000 U	18	1,500
Aroclor 1221	59 U	7.8 U	4.0 U	2,800 U	240 U	40 U	12 U	79 U	26,000 U	7.8 U	240 U
Aroclor 1232	59 U	16 U	4.0 U	2,800 U	240 U	40 U	12 U	79 U	26,000 U	7.8 U	240 U
Total PCBs	330	66 J	65 J	3,900	3,740 J	400	120 J	780	92,000	38.3 J	1,500
TPH (mg/kg)											
Diesel	36	21	19	84	2,300	120	14	63	250	8.9	1,600
Motor Oil	140	99	70	460	9,700	670	66	360	1,100	61	3,000

¹T5 is duplicate of T2.

S = Seattle field split

B = Boeing field split

Table B-3b: Slip 4 drainage basin inline sediment sample results compared to Sediment Management Standards.

	Slip 4 Storm Drains										
	SQS	CSL	MH100 North+ central lat #2	MH100 North+ central lat #2	MH221A Central lat #1, d/s Boeing Field	MH221A Central lat #1, d/s Boeing Field	MH363 North lat, d/s Steampl	MH363 North lat, d/s Steampl	MH229A Central lat #1, d/s runway	MH229A Central lat #1, d/s runway	MH32 I-5 SD at Airport Wy
Date			2/16/05 S	2/16/05 B	2/16/05 S	2/16/05 B	2/16/05 S	2/16/05 B	2/16/05 S	2/16/05 B	8/11/05 S
TOC (percent)			6.11	6.6	1.09	1	1.11	0.76	4.34	3.88	0.739
Metals (mg/kg DW)											
As	57	93	20	20	40	12	9	8	30	30	10 U
Cu	390	390	88.9	102	126	38.5	64.1	45.1	69.7	85.5	61.2
Pb	450	530	134	142	94	50	51	110	120	155	207
Hg	0.41	0.59	0.2	0.2	0.09	0.09	0.48	0.7	0.07	0.07	0.05 U
Zn	410	960	377	411	572	332	208	272	699	1,130	186
LPAH (mg/kg OC)											
Acenaphthene	16	57	2 U	2.7 U	17 U	6 U	5 U	8 U	18	24	3 U
Acenaphthylene	66	66	2 U	2.7 U	17 U	6 U	5 U	8 U	2	6 U	3 U
Anthracene	220	1,200	2 U	2.7	17 U	7	6	8 U	18	31	3 U
Fluorene	23	79	2 U	2.7 U	17	7	5 U	8 U	19	28	3 U
Naphthalene	99	170	2 U	0.9 U	5 U	6 U	5 U	8 U	2	6 U	3
Phenanthrene	100	480	8	6.7	40	30	36	34	141	229	3 U
HPAH (mg/kg OC)											
Benzo(a)anthracene	110	270	5	6	30	28	31	37	44	77	3 U
Benzo(a)pyrene	99	210	5	7	43	40	30	39	46	88	4
Benzo (b+k)fluoranthene	230	450	13	18	102	111	72	100	122	232	7
Benzo(g,h,i)perylene	31	78	3	3	28	23	15	22	19	34	3 U
Chrysene	110	460	9	9	55	49	45	53	60	108	4
Dibenzo(a,h)anthracene	12	33	2 U	1 U	17 U	6 U	5 U	8 U	9	6 U	3 U
Fluoranthene	160	1,200	16	13	101	92	76	99	154	284	6
Indeno(1,2,3-c,d)pyrene	34	88	4	3	35	26	17	24	23	39	3 U
Pyrene	1 000	1 400	12	12	73	87	57	87	113	196	7
Phthalates (mg/kg OC)											
Bis(2-ethylhexyl)phthalate	47	78	25	30	73	76	39	66	28	57	24
Butylbenzylphthalate	4.9	64	2	1.3	17 U	6 U	5 U	8 U	1	6 U	3 U
Diethylphthalate	61	110	2 U	0.9 U	17 U	6 U	5 U	8 U	1 U	6 U	3 U
Dimethylphthalate	53	53	2 U	0.9 U	17 U	6 U	5 U	8 U	1 U	6 U	3 U
Di-n-butylphthalate	220	1,700	2 U	0.9 U	17 U	6 U	5 U	8 U	3	6 U	3 U
Di-n-octylphthalate	58	4,500	2 U	1.1	17	12	5	9	3	6	3 U
PCBs (mg/kg OC)											
Aroclor 1016			4 U	1.4 U	11 U	12 U	108 Y	125 U	0.4 U	3.6 U	3 U
Aroclor 1242			4 U	1.4 U	11 U	12 U	85 Y	125 U	0.4 U	3.6 U	3 U
Aroclor 1248			4 U	1.4 U	11 U	12 U	216 Y	250 U	0.4 U	3.6 U	3 U
Aroclor 1254			16	24	54	96	2,793	921	3	95	3 U
Aroclor 1260			13 P	6 P	38	53	342 Y	125 U	4 P	49	3 U
Aroclor 1221			4 U	1.4 U	11 U	12 U	42 U	63 U	0.4 U	3.6 U	3 U
Aroclor 1232			4 U	1.4 U	11 U	12 U	126 Y	184 U	0.4 U	3.6 U	3 U
Total PCBs	12	65	30 P	30 P	92	149	2,793	921	7 P	144	3 U
TPH (mg/kg)											
Diesel		2,000 ^a	88	40	120	120	120	47	110	200	120 U
Motor Oil		2,000 ^a	380	190	270	210	680	190	380	1,000	290

Detected values shown in bold type.

^aMTCA Method A soil cleanup level for industrial use.

U = Chemical not detected at reported concentration

Y = Chemical not detected at the reported concentration. Reporting limit raised due to chromatographic interference.

J = Chemical concentration is reported as estimate.

P = Chemical detected on both chromatographic columns, but values differ by >40% RPD with no obvious interference.

Exceeds SQS

Exceeds CSL or MTCA Method A soil cleanup level for industrial use.

Table B-3b: Slip 4 drainage basin inline sediment sample results compared to Sediment Management Standards.

	Georgetown Flume Samples													
	SQS	CSL	T1 Flume 15' u/s of box culvert	T2 Flume at S Myrtle St	T5 ¹ Flume at S Myrtle St	T3 Flume upstream of S Willow St	T4 Head of flume	T6 MH100 u/s of E Marginal Wy S	P1 Flume off of 8" plugged pipe	P2 Flume off of 8" pipe near S Willow St	P3 Flume off of 15" plugged pipe	P4 Flume off of 8" pipe at S Myrtle St	P5 Ditch at S Myrtle St	
Date			3/24/05 S	3/24/05 S	3/24/05 S	3/25/05 S	3/24/05 S	3/25/05 S	3/25/05 S	3/25/05 S	3/25/05 S	3/24/05 S	3/24/05 S	
TOC (percent)			3.92	1.43	1.17	2.25	8.71	2.68	0.711	2.47	5.27	0.773	6.86	
Metals (mg/kg DW)														
As	57	93	11	7 U	7 U	7 U	40	7 U	7 U	13	20	6 U	10 U	
Cu	390	390	63.2	18.5	20.2	54.6	314 J	79.6	18	56.6	133	12.8	95.1	
Pb	450	530	99	14	15	263	590 J	61	16	69	501	10	73	
Hg	0.41	0.59	0.1	0.05 U	0.05 U	0.41	1.7	0.08	0.05 U	0.18	1	0.06 U	0.08	
Zn	410	960	218	53.8	61.3	180	1,130	240	60.8	238	766	52.7	195	
LPAH (mg/kg OC)														
Acenaphthene	16	57	7	1 U	2	17	8	3	3 U	2 U	2 U	2 U	23 U	
Acenaphthylene	66	66	4	1 U	2	10	31	1 J	4	4	2 U	2	23 U	
Anthracene	220	1,200	16	4	8	26	29	8	14	11	2	9	23 U	
Fluorene	23	79	6	1 U	2 U	24	22	2	3 U	2 J	2 U	2 U	23 U	
Naphthalene	99	170	8	1 U	2 U	4	28	2 U	3 U	2 U	2 U	2 U	23 U	
Phenanthrene	100	480	115	3	6	276	126	28	14	10	10	18	23 U	
HPAH (mg/kg OC)														
Benzo(a)anthracene	110	270	33	7	13	62	91	19	21	15	7	9	23 U	
Benzo(a)pyrene	99	210	33	17	26	22	99	21	18	12	9	11	23 U	
Benzo (b+k)fluoranthene	230	450	82	36	55	82	234	53	52	43	22	31	47 U	
Benzo(g,h,i)perylene	31	78	15	6	11	9	29	8	7	5	4	4	23 U	
Chrysene	110	460	59	11	18	67	96	28	32	26	10	21	12 J	
Dibenzo(a,h)anthracene	12	33	6	2	4	2 J	11	2 J	3 U	1 J	2 U	2 U	23 U	
Fluoranthene	160	1,200	161	14	22	271	207	60	75	49	21	63	15	
Indeno(1,2,3-c,d)pyrene	34	88	17	6	10	10	34	8	8	5	4	4	23 U	
Pyrene	1,000	1,400	82	9	15	147	161	45	42	34	18	30	17	
Phthalates (mg/kg OC)														
Bis(2-ethylhexyl)phthalate	47	78	51	10	12	26	2	75	17	23	40	18	55	
Butylbenzylphthalate	4.9	64	3	1 U	2 U	3 U	2 U	4	3 U	2 U	3	2 U	23 U	
Diethylphthalate	61	110	2 U	1 U	2 U	3 U	2 U	2 U	3 U	2 U	2 U	2 U	23 U	
Dimethylphthalate	53	53	2 U	1 U	2 U	3 U	2 U	2 U	3 U	2 U	2 U	2 U	23 U	
Di-n-butylphthalate	220	1,700	2	1 U	2 U	3	2 U	2 U	3	3	3	2 U	23 U	
Di-n-octylphthalate	58	4,500	2 U	1 U	2 U	3 U	2 U	2	3 U	9	3	2 U	23 U	
PCBs (mg/kg OC)														
Aroclor 1016			2 U	1 U	0 U	124 U	3 U	1 U	2 U	3 U	493 U	1 U	3 U	
Aroclor 1242			2 U	1 U	0 U	124 U	3 U	1 U	2 U	3 U	493 U	1 U	3 U	
Aroclor 1248			2 U	1	1 J	124 U	17 J	3 U	4	9	493 U	1	3 U	
Aroclor 1254			5	2 J	2 J	173	20	9	8 J	18	1,746	2 J	7 U	
Aroclor 1260			4	2	2	124 U	6	6	5	5	493 U	2	22	
Aroclor 1221			2 U	1 U	0 U	124 U	3 U	1 U	2 U	3 U	493 U	1 U	3 U	
Aroclor 1232			2 U	1 U	0 U	124 U	3 U	1 U	2 U	3 U	493 U	1 U	3 U	
Total PCBs	12	65	8	5	6	173	43	15	17	32	1,746	5	22	
TPH (mg/kg)														
Diesel		2,000 ^a	36	21	19	84	2,300	120	14	63	250	8.9	1,600	
Motor Oil		2,000 ^a	140	99	70	460	9,700	670	66	360	1,100	61	3,000	

¹T5 is duplicate of T2.

S = Seattle field split

B = Boeing field split

Table B-4a: Slip 4 drainage basin catch basin and sediment sample results (dry weight).

	SQS	CSL	CB37	CB44	CB45	CB46	CB48	CB79	CB80	RCB49	S1
Date			6/22/04	12/8/04	12/22/04	12/22/04	2/20/05	11/9/05	11/9/05	11/8/05	11/9/05
TOC (percent)			4.74	24.6	9.74	10.4	1.57	6.42	2.68	4.06	3.1
Metals (mg/kg DW)											
As	57	93	20 U	12	20	20	12	30	6 U	20 U	11
Cu	390	390	173	142	6,320	5,660	51.5	207	85.2	85	69.9
Pb	450	530	250	123	481	396	343	114	29	79	73
Hg	0.41	0.59	0.08	0.12	0.30	0.20	0.32	0.2	0.05 U	0.05 U	0.14
Zn	410	960	1,220	524	3,420	3,530	657	758	268	357	172
LPAH (ug/kg DW)											
Acenaphthene			170	140 U	760	1,600 U	130	90 U	66	20 U	35 U
Acenaphthylene			140 U	140 U	390 U	1,600 U	59 U	90 U	42 U	20 U	35 U
Anthracene			820	140 U	2,100	5,000	110	6,400	67 M	16 J	21 J
Fluorene			350	140 U	1,300	3,000	130	1,300	340	20 U	35 U
Naphthalene			140 U	140 U	390 U	1,600 U	470	160	89	20 U	35 U
Phenanthrene			3,000	220	17,000	35,000	3,100	1,700	1,100	68	78
HPAH (ug/kg DW)											
Benzo(a)anthracene			610	140 U	13,000	27,000	1,300	730	160	60	81
Benzo(a)pyrene			200	140 U	15,000	32,000	1,400	830	170	120	140
Benzo(b)fluoranthene			480	180	15,000	34,000	3,100	1,200	250 M	200	250
Benzo(k)fluoranthene			320	180	15,000	34,000	1,500	1,300	240 M	170	190
Benzo(a)fluoranthene			800	360	30,000	68,000	4,600	2,500	490 M	370	440
Benzo(g,h,i)perylene			140 U	140 U	7,300	16,000	660	570	140	110	87
Chrysene			1,000	290	20,000	43,000	2,100	1,800	400	120	160
Dibenzo(a,h)anthracene			140 U	140 U	2,700	5,400	99	150	42 U	14 J	35
Fluoranthene			3,600	410	31,000	85,000	4,700	1,700	360	180	190
Indeno(1,2,3-c,d)pyrene			140 U	140 U	8,600	19,000	940	410	62	41	61
Pyrene			2,600	290	23,000	49,000	3,100	5,300	1,000	180	290
Phthalates (ug/kg DW)											
Bis(2-ethylhexyl)phthalate			1,600	3,910	8,800	30,000	88	120,000	38,000	1,400	5,500
Butylbenzylphthalate			1,300	430	490	1,600 U	59 U	90 U	1,800	1,100	140
Diethylphthalate			140 U	140 U	390 U	1,600 U	59 U	90 U	42 U	20 U	35 U
Dimethylphthalate			280	850	620	1,600 U	59 U	90 U	1,900	44	35 U
Di-n-butylphthalate			140 U	140 U	1,200	1,600 U	59 U	90 U	360 B	54 B	63 B
Di-n-octylphthalate			140 U	140 U	1,200	1,600 U	59 U	4,000	1,800	79	35 U
PCBs (ug/kg DW)											
Aroclor 1016			20 U	20 U	58 U	47 U	19 U	99 U	98 U	98 U	99 U
Aroclor 1242			20 U	20 U	58 U	47 U	19 U	99 U	98 U	98 U	99 U
Aroclor 1248			20 U	20 U	58 U	47 U	19 U	99 U	98 U	98 U	99 U
Aroclor 1254			20 U	49 Y	170	250	250	160	98 U	98 U	99 U
Aroclor 1260			20 U	180	300	430	77 Y	140	98 U	98 U	99 U
Aroclor 1221			20 U	20 U	58 U	47 U	19 U	99 U	98 U	98 U	99 U
Aroclor 1232			20 U	20 U	58 U	47 U	19 U	99 U	98 U	98 U	99 U
Total PCBs			20 U	180	470	680	250	300	98 U	98 U	99 U
TPH (mg/kg)											

Table B-4a: Slip 4 drainage basin catch basin and sediment sample results (dry weight).

	SQS	CSL	CB37	CB44	CB45	CB46	CB48	CB79	CB80	RCB49	S1
Diesel			180	85	950	1,900	98	6,000	1,200	68	280
Motor Oil			650	790	4,700	4,600	210	13,000	2,300	450	1,500

Detected values shown in bold type.

U = Chemical not detected at reported concentration

Y = Chemical not detected at the reported concentration. Reporting limit raised due to chromatographic interference.

P = Chemical detected on both chromatographic columns, but values differ by >40% RPD with no obvious interference.

M = Estimated value. Analyte detected and confirmed by analyst, but spectral match patterns are low.

	Exceeds SQS
	Exceeds CSL or MTCA Method A soil cleanup level

Table B-4b: Slip 4 drainage basin catch basin and sediment samples compared to Sediment Management Standards.

	SQS	CSL	CB37	CB44	CB45	CB46	CB48	CB79	CB80	RCB49	S1
Date			6/22/04	12/8/04	12/22/04	12/22/04	2/20/05	11/9/05	11/9/05	11/8/05	11/9/05
TOC (percent)			4.74	24.6	9.74	10.4	1.57	6.42	2.68	4.06	3.1
Metals (mg/kg DW)											
As	57	93	20 U	12	20	20	12	30	6 U	20 U	11
Cu	390	390	173	142	6,320	5,660	52	207	85.2	85	69.9
Pb	450	530	250	123	481	396	343	114	29	79	73
Hg	0.41	0.59	0.08	0.12	0.30	0.20	0.32	0.2	0.05 U	0.05 U	0.14
Zn	410	960	1,220	524	3,420	3,530	657	758	268	357	172
LPAH (mg/kg OC)											
Acenaphthene	16	57	4	1 U	8	15 U	8	1 U	2	0.5 U	1 U
Acenaphthylene	66	66	3 U	1 U	4 U	15 U	4 U	1 U	2 U	0.5 U	1 U
Anthracene	220	1,200	17	1 U	22	48	7	100	3 M	0.4 J	1 J
Fluorene	23	79	7	1 U	13	29	8	20	13	0.5 U	1 U
Naphthalene	99	170	3 U	1 U	4 U	15 U	30	2	3	0.5 U	1 U
Phenanthrene	100	480	63	1	175	337	197	26	41	2	3
HPAH (mg/kg OC)											
Benzo(a)anthracene	110	270	13	1 U	133	260	83	11	6	1	3
Benzo(a)pyrene	99	210	4	1 U	154	308	89	13	6	3	5
Benzo(b)fluoranthene	---	---	10	1	154	327	197	19	9 M	5	8
Benzo(k)fluoranthene	---	---	7	1	154	327	96	20	9 M	4	6
Benzo(b+k)fluoranthenes	230	450	17	1	308	654	293	39	18 M	9	14
Benzo(g,h,i)perylene	31	78	3 U	1 U	75	154	42	9	5	3	3
Chrysene	110	460	21	1	205	413	134	28	15	3	5
Dibenzo(a,h)anthracene	12	33	3 U	1 U	28	52	6	2	2 U	0 J	1
Fluoranthene	160	1,200	76	2	318	817	299	26	13	4	6
Indeno(1,2,3-c,d)pyrene	34	88	3 U	1 U	88	183	60	6	2	1	2
Pyrene	1,000	1,400	55	1	236	471	197	83	37	4	9
Phthalates (mg/kg OC)											
Bis(2-ethylhexyl)phthalate	47	78	34	16	90	288	6	1,869	1,418	34	177
Buty benzylphthalate	5	64	27	2	5	15 U	4 U	1 U	67	27	5
Diethylphthalate	61	110	3 U	1 U	4 U	15 U	4 U	1 U	2 U	0.5 U	1 U
Dimethylphthalate	53	53	6	3	6	15 U	4 U	1 U	71	1	1 U
Di-n-butylphthalate	220	1,700	3 U	1 U	12	15 U	4 U	1 U	13 B	1 B	2 B
Di-n-octylphthalate	58	4,500	3	1	12	15	4	62	67	2	1 U
PCBs (mg/kg OC)											
Aroclor 1016			0.4 U	0.1 U	0.6 U	0.5 U	1.2 U	1.5 U	3.7 U	2.4 U	3.2 U
Aroclor 1242			0.4 U	0.1 U	0.6 U	0.5 U	1.2 U	1.5 U	3.7 U	2.4 U	3.2 U
Aroclor 1248			0.4 U	0.1 U	0.6 U	0.5 U	1.2 U	1.5 U	3.7 U	2.4 U	3.2 U
Aroclor 1254			0.4 U	0.2 Y	1.7	2.4	15.9	2.5	3.7 U	2.4 U	3.2 U
Aroclor 1260			0.4 U	0.7	3.1	4.1	4.9 Y	2.2	3.7 U	2.4 U	3.2 U
Aroclor 1221			0.4 U	0.1 U	0.6 U	0.5 U	1.2 U	1.5 U	3.7 U	2.4 U	3.2 U
Aroclor 1232			0.4 U	0.1 U	0.6 U	0.5 U	1.2 U	1.5 U	3.7 U	2.4 U	3.2 U
Total Aroclor	12	65	0.4 U	0.7	4.8	6.5	15.9	4.7	3.7 U	2.4 U	3.2 U
TPH (mg/kg)											

Table B-4b: Slip 4 drainage basin catch basin and sediment samples compared to Sediment Management Standards.

	SQS	CSL	CB37	CB44	CB45	CB46	CB48	CB79	CB80	RCB49	S1
Diesel	2,000 ^a		180	85	950	1,900	98	6,000	1,200	68	280
Motor Oil	2,000 ^a		650	790	4,700	4,600	210	13,000	2,300	450	1,500

Detected values shown in bold type.

^aMTCA Method A soil cleanup level for unrestricted use.

U = Chemical not detected at reported concentration

Y = Chemical not detected at the reported concentration. Reporting limit raised due to chromatographic interference.

M = Estimated value. Analyte detected and confirmed by analyst, but spectral match patterns are low.

J = Chemical concentration is reported as estimate.

	Exceeds SQS
	Exceeds CSL or MTCA Method A soil cleanup level

Lower Duwamish Waterway Slip 4 Early Action Area

Appendix C Approximate Post-Construction Elevations and Habitat Areas for Alternatives 1–4

